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COJFRC Symposium
Proceedings O-P-15

Ontario | Ministry of Natural Resources

PRIMEVAL IMPROVEMENT: THE NEW FORESTRY AGE

Proceedings of a Symposium sponsored by the Ontario Ministry of Natural Resources and the Great Lakes Forestry Centre under the auspices of the Canada-Ontario Joint Forestry Research Committee

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Proceedings of a Symposium sponsored by the
Ontario Ministry of Natural Resources
and the
Great Lakes Forestry Centre
under the auspices of the
Canada-Ontario Joint Forestry Research Committee
Thunder Bay, Ontario
21-23 October, 1986

R.L. GALLOWAY, R.M. GREET, D.W.J. McGOWAN

and J.D. WALKER, Cochairmen

GREAT LAKES FORESTRY CENTRE

CANADIAN FORESTRY SERVICE

GOVERNMENT OF CANADA

1987

COJFRC SYMPOSIUM PROCEEDINGS O-P-15

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Catalogue No. Fo18-3/15-1987E
ISBN 0-662-15311-1
ISSN 0708-305X

FOREWORD

"Modern Technology in Forest Management" was the theme of the 15th symposium conducted under the auspices of the Canada-Ontario Joint Forestry Research Committee (COJFRC). These symposia are designed to ensure effective communication of forest research results and innovative operational practices to forest managers and administrators.

The symposium was held on the campus of Lakehead University's School of Forestry in Thunder Bay, Ontario. More than 170 delegates were in attendance, representing the Ontario Ministry of Natural Resources (41%), the Canadian Forestry Service (16%), the Ontario forest industry (15%), universities (7%), other provincial and United States forest services (7%), forestry consultants (6%), and assorted government and private organizations (8%).

The purpose of the 1986 symposium was to describe and demonstrate how the technological "leading edge" has, or will have, an impact on forest management, enhancement and renewal. There were opportunities to talk and work with people who are in the forefront of developments in forestry.

One and a half days were devoted to formal presentations, which were divided into four sessions:

Perspectives (Chairman: A.J. Kayll, Lakehead University School of Forestry)

Forest Harvesting and Renewal (Chairman: M. Squires, Abitibi-Price Inc., Thunder Bay)

Forest Maintenance (Chairman: T.G. Eiber, Lakehead University School of Forestry)

High-Tech at the Desk (Chairman: J.E. Osborne, Ontario Ministry of Natural Resources)

The second day of the symposium was devoted to workshops (13) and tours of local wood processing plants (4). These sessions were of two main types:

a) upgrading courses in, for example, site evaluation, nursery stock evaluation, and wildlife management

b) information sessions on new technology such as microcomputers, geographic information systems, and electronic recording of field data.

Between workshops, delegates had the opportunity to study the poster and equipment displays prepared by government (4) and private (4) organizations on a variety of forest management practices.

Unfortunately, the following two papers and some of the summaries of workshops, tours and poster displays were not available for printing:

G.J. Garner, Great Lakes Forest Products, Thunder Bay
Subject: forest harvesting and renewal

P. Reynolds, Forest Pest Management Institute, Sault Ste. Marie
Subject: herbicide development and use

The use of trade names in the papers presented does not constitute endorsement by the participants or by the organizations with which they are affiliated.

The members of the symposium committee express their appreciation to the local organizing committee in Thunder Bay for a job well done. This group consisted of D. Dool, Great Lakes Forest Products, T.G. Eiber of Lakehead University and P. McAlister of the Ontario Ministry of Natural Resources. Thanks are also extended to the faculty and students of Lakehead University School of Forestry for the use of their laboratories and lecture facilities.

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OPENING REMARKS

J.H. Cayford, Director General
Canadian Forestry Service
Great Lakes Forestry Centre
Sault Ste. Marie, Ontario

Good morning! It is my pleasure to join with representatives of Lakehead University and the Ontario Ministry of Natural Resources in welcoming all of you to the 15th annual symposium sponsored by the Ontario Ministry of Natural Resources and the Great Lakes Forestry Centre of the Canadian Forestry Service and organized through the Canada-Ontario Joint Forestry Research Committee (COJFRC).

The primary purpose of these symposia is to ensure that Ontario forest managers are kept informed of current research findings and technology. A review of the topics of past symposia reveals a very wide coverage of important forestry issues. Subjects have ranged from management of jack pine, black spruce, boreal mixedwoods, southern hardwoods and white and red pine to tree improvement, forest fire research, container planting, and spruce budworm control. The proceedings of these symposia collectively provide a very comprehensive coverage of Ontario forestry issues. I am confident that this symposium, which focusses on modern technology in forestry, will be as informative and stimulating as past symposia.

It is probable that this will be the last symposium organized by COJFRC. The Ontario Forestry Council, consisting of representatives from forest industry, universities and the federal and provincial governments, has recently recommended certain changes in the structure of the various forest research committees. The basic recommendation is that there be an Ontario Forestry Research Committee that would assume the responsibilities currently undertaken by COJFRC and by the Ontario Tree Improvement and Forest Biomass Institute and Great Lakes Forestry Centre Advisory Committees. This committee would include industrial and university representation as well as federal and provincial government representation. I am assured that the COJFRC working groups will continue to function and that the responsibility for these annual symposia will be included in the terms of reference for the committee. Thus, while these COJFRC symposia as we know them will terminate, we can be assured that they will continue with even broadened sponsorship.

Before I conclude these brief remarks I would like to acknowledge the work of the organizing committee in arranging this symposium. We have four cochairmen whom I would like to recognize: Rick Greet, Great Lakes Forestry Centre, Rob Galloway, Ontario Ministry of Natural Resources, Dave McGowan, Ontario Ministry of Natural Resources (but with the Great Lakes Forestry Centre during the initial planning), and John Walker, Petawawa National Forestry Institute. My thanks to all of you, as well as to those who have served on the committee, for a job well done.

I appreciate the opportunity to welcome all of you here to the 1986 COJFRC symposium and I hope that each and every one of you will benefit from your attendance.

Thank you.

* * * * * * * * * * * * *

L. Lambert, Director
Forest Resources Branch
Ontario Ministry of Natural Resources
Toronto, Ontario

I want to apologize to each of the organizers and the participants on behalf of Ken Armson, who as you know is an ardent proponent and enthusiastic supporter of this type of symposium. Ken was keenly looking forward to being here this morning and participating over the next couple of days. Unfortunately, he is very deeply and totally caught up in the countervail issue and negotiations this week.

Ken would ask that I lay two charges before each of the seminar participants.

The first is that we be forward thinking and positive over the next couple of days, as there is a very real need for improvement in our awareness and use of the most current technology and processes. However, that thought comes with a major caveat. It is a request that we maintain a perspective. For, as much as we require forward movement, the timing and direction must be appropriate; we do not want change and movement simply for the sake of motion.

I would remind you that we in the forestry sector are not in a "high-tech" industry — we never have been and never will be. Our strength is in doing basics, but in doing them exceedingly well. We have a massive land resource, an excellent forest resource, superbly competent and dedicated human resources, and we are very active in seeking out, developing and transferring relevant technology.

My interpretation of that first charge is that we need and want substantial improvement, but as we move toward that objective, we must remember that we're bread-and-butter folks.

So let's come down heavy on those who, over the next couple of days, offer only the glitz and the distraction of smoke and mirrors; but equally, let's listen attentively and be totally receptive to those who can suggest realistic and affordable opportunities for modest, genuine and relevant improvement.

The second charge is substantially more succinct. It's that we work hard, that we play hard, and that we have a very productive and enjoyable symposium.

PERSPECTIVES

PRODUCTIVITY AND INNOVATION: CHALLENGES TO THE MANAGEMENT OF OUR RESOURCE INDUSTRIES

E.H. Dudgeon
Associate Vice-President, Engineering
National Research Council of Canada
Ottawa, Ontario

Abstract.—The resource industries are major contributors to Canada's balance of trade. Competition from resource-rich, low-wage, developing countries, and from industrially developed countries committed to advanced technology, threatens Canada's traditional industries. By international standards, Canadian industry is a very poor contributor to new technology through research. If our resource industry is to remain competitive on an international scale it must increase the value added to its products by innovative research and development. Industry cannot look only to government to supply the incentive; the responsibility is with the management of Canadian industry itself.

Résumé.—Les industries des ressources jouent un rôle majeur dans la balance commerciale du Canada. La concurrence des pays industrialisés qui sont à la pointe de la technologie et des pays en développement riches en ressources et à faibles salaires représente une menace pour les industries traditionnelles du Canada. Comparativement à l'industrie des autres pays, l'industrie canadienne a très peu contribué à la création de nouvelles techniques. Pour rester compétitive à l'échelle internationale, notre industrie des ressources doit chercher à accroître la valeur ajoutée de ses produits par des programmes innovateurs de recherche et de développement. L'industrie ne peut compter uniquement sur les gouvernements pour donner l'élan dans ce domaine; c'est une responsabilité qui revient aux dirigeants de l'industrie canadienne.

The events of recent weeks must have a critical impact on all aspects of the management of our forest industries. The countervailing duty recently imposed on shingles and shakes by the United States, and now proposed for softwood lumber, has serious implications not just for the short-term dislocations these actions will cause, but also for the long-term security of the forest industry.

We might be optimistic and believe that these problems will disappear when we have 'free trade' with the United States. However, I do not believe that any development of a trade agreement between Canada and our largest trading partner, though valuable in many respects, will completely eliminate all such particular protectionist measures. No sovereign country will stand back and let a foreign country replace a significant portion of its basic resource or manufacturing capability. The impact on employment and the imagined effect on national security will make a fully laissez-faire attitude to foreign imports unacceptable. Therefore, I believe that our industries must be prepared for such protectionist measures. Industries, particularly those such as the forest industry, which rely for their continued well-being and their success on a large export market must continue to develop alternatives to cope with such protectionist measures. Our exporting industries must be very conscious of the attitudes of the industry with which they are competing in the

countries to which they are exporting. They should be sensitive to the pressures building up in those countries among their direct competitors and they should be considering ways to side-step such competitors by increasing production efficiency through improved processes, or by changing product mix through innovation and research. It is in these aspects of innovation and improved processes, perhaps, that someone who is neither forester nor trade expert can comment on the needs of a major exporting industry such as the forest industry.

For someone with my background, coming from an organization devoted to research and development, and convinced of the vital importance of research, development and advanced technology as the prerequisite for industrial success in a very competitive world, the theme of this Canada-Ontario Joint Forestry Research Symposium is most appropriate. I was advised, when I was invited to talk at this symposium, that it would concentrate on present and future use of modern technology in a wide range of forest management activities.

I would like to comment on the importance of research and new technology generally, and on the critical role of management in supporting adequate levels of research and the use of this new technology. Management is ultimately responsible for dealing with the essential need for innovation in Canadian industry. Although I shall refer to examples in the forest industry because of their special relevance to this audience, concern about the state of innovation in Canada and of new technology especially is broadly based. *All* industries, not only our resource industries, must address the need for increased research and development and innovation.

Despite much talk about Canada's position as a highly developed, "high-tech" industrial nation, we should be realistic and accept that Canada is, and will continue to be for at least the near future, a resource-based economy.

We must recognize our inherent advantage in our wealth of natural resources and we must build on it. The development of innovative, high-tech companies is important as a source of new technology, but as a source of Canadian national wealth such companies, which are generally small, cannot replace the mammoth contributions of our resource-based industrial sector. We will allow at our peril the decline and destruction of our resource industries by foreign competition.

A recent study[1] by the Ministry of State for Science and Technology has highlighted the importance of our resource industry, and its related infrastructure, to Canada's economy.

The study showed that the resource sector of our economy (energy, mining, agriculture, forestry, fisheries) contributed close to 23% of the total gross domestic product (GDP) of the country. But, perhaps even more significantly, this resource sector contributed, in 1984, a positive balance of trade of $37.6 billion in our favor.

Canada's basic manufacturing industry contributed some 19% to our GDP but had a negligible impact on our balance of trade, with a positive balance of only $0.7 billion.

Canada's high-tech industry sector, the glamor sector with some high profile successes (and failures) in telecommunications, computer accessories and instrumentation, contributed only 4% to the Canadian GDP. Further, our needs for high-tech products, many of them for use in the service and home markets, were not met to any great extent by our own high-tech industry. In high-tech products we had a net *deficit* in our trade balance of $12 billion.

The importance of our resource industry must be recognized when it is realized that one resource industry alone, the forest industry, contributed a positive balance of trade greater than the entire high-tech deficit--a net positive balance of $14.7 billion in 1984.

This beneficial contribution of Canada's resource industry continues. The mid-year forecast of the Financial Post (30 August 1986) estimated that the next excess of exports over imports in forest products (lumber, pulp and paper) for 1986 would be close to $16 billion.

With this positive outlook for our current forest industry it would be expected that this industry could afford to be confident and relaxed about the future. In my view, however, nothing could be more dangerous. Canada's resource industry is threatened by low-wage, resource-rich foreign countries. And there are threats from some high-wage, resource-limited, innovative foreign countries such as Sweden and Finland.

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[1] Anon. 1986. Strengths and weaknesses of Canadian industry. Min. State Sci. Tech., Ind. Trade Tech. Sect., Ottawa, Ont. Intern. Stud.

One answer to the threatened future of our resource industry is to apply high-tech to our resource industry. To compete against low-wage countries our industry must apply the latest technology to ensure high productivity and innovative products.

By most world standards Canada has not been a backward country in terms of its productive efficiency. On average, Canadian industry is highly efficient. Canada is probably still the second most productive country in the world after the United States. The resource industry is a major contributor to Canada's generally good international standing in terms of productivity. However, our manufacturing industry is some 20 to 25% less productive than that of the United States and is probably less productive than those of Sweden and Switzerland.[2]

Canada's forest industry is also a productive one, particularly when compared with that of its largest market, the United States. In the softwood lumber industry, which is very much a topic of international discussion because of its success in the United States market, several studies have shown Canadian softwood lumber productivity to be consistently higher than that of the United States. The amount of the difference appears to be related to the intensity of the concerns of American producers as expressed to their own government. In 1985, in preparation for a review of the increasing lumber exports to the United States from Canada, the United States International Trade Commission (ITC) undertook a study to compare the softwood lumber industries in the two countries. The ITC report issued in the fall of 1985 (Anon. 1986) found that Canadian producers were as much as 60% more productive than their American counterparts. This difference was quickly disputed by the American producers, who were seeking tariff protection on the principle that Canadian industry was unfairly subsidized by the Canadian government. The ITC undertook a second look at productivity differences and, early in January 1986, concluded that, on the basis of "refined data", Canadian softwood lumber employees were only 26% more productive in 1984 than their American counterparts (Anon. 1986). Further, if British Columbia's industry is compared with the American industry in Idaho, Montana, Oregon and Washington (where mills have a product mix similar to that in Canada), the productivity gap in favor of Canada was only 6%, according to the ITC. Productivity differences were attributable mainly to a narrower product mix, larger mills and minimal hardwood processing in Canada.

In all the reviews, the American studies found that the Canadian softwood lumber industry was more productive than its counterpart in the United States. And we can be certain that American studies were not likely to exaggerate this comparison when their own softwood industry was trying to claim that the low cost of Canadian softwood in the United States was due to unfair government subsidies to the Canadian industry, not to more efficient management and labor practices.

However, the forest industry cannot afford to be complacent. One country's productivity advantage at one point in time can be overtaken and surpassed by another country with a determined effort to succeed. If our productivity is high now, we cannot afford to coast, or rest on our current status. Other countries will not stand still. A strategy to improve productivity in selected industries can have dramatic effects, and this could apply even in an industry as mature and well developed as the forest industry.

We can look at another basic industry, the steel industry, to see what can be done with an effective national commitment. Determined that an efficient steel industry was essential for industrial development, Japan set out in the 1960s to modernize its steel industry. Between 1964 and 1975 Japan increased productivity in that industry dramatically (Kimura 1985). The man-hours required to produce a ton of steel fell from 25.2 to 9.2. During the same period, steel productivity in the United States increased only slightly, the man-hours per ton of steel dropping from 13.1 to 10.9. Thus, in 1964 the Japanese required twice as much labor as the United States to make a ton of steel, but by 1975 productivity in Japan had increased to such an extent that they required only nine-tenths as much labor as the United States for this purpose. Furthermore, the American plants still used 150% more *energy* than Japanese plants to make the same ton of steel. A determined will to increase productivity in an industrial sector can be very successful, but it requires a committed management and responsive labor force.

Already in certain sectors of the forest industry we see examples of Canada falling seriously behind our competitors in productivity. In the 1970s Swedish newsprint mills were facing severe competition from North America. The industry underwent a painful process of rationalization and modernization.

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[2] For example, in hard rock mining, which makes a substantial positive contribution to Canada's balance of trade, Canada is a world leader. Canada's mining productivity has been estimated at 1.6 times that of the United States.

Nearly a quarter of the country's mills were forced to close but a major effort was made to develop new, larger, more efficient paper machines that could restore Swedish competitiveness in the export market. Old machines were replaced with new, very wide, high-speed machines capable of very high production. By the end of 1985 all Swedish newsprint was produced on machines with a capacity greater than 100,000 tons per year, while 40% of Canadian production came from smaller, less efficient machines with a capacity of less than 100,000 tons (Bayliss 1985). Eighty percent of Swedish newsprint was produced on machines with a capacity of over 150,000 tons per year; in Canada only 20% of newsprint capacity came from machines of this size. This effort by Sweden has enabled it to recapture its European market. The costs of continually upgrading productivity are high, but industry neglects the race at its peril.

Improved productivity and product innovation can be obtained only by the use of the best and the newest technology. Many studies have shown that research and development are primary factors in technical innovation as well as in the development of new products and the maintenance of a high level of industrial productivity.

Of course, Canadian industry cannot develop by itself all the new technology it needs to remain competitive. Canada develops only 2-3% of the world's new technology, and therefore must buy or license much of the remaining 97-98% that is generated in foreign countries. However, to wait until that 97% becomes generally available in the available literature would be completely unsatisfactory for a trading country like Canada, because it would always be lagging behind foreign competition. Therefore, Canada must be prepared to buy or license much of the new technology that is generated in foreign countries.

Buying or licensing technology is, in a sense, less risky than developing our own through research and development. Certainly the procedure has been used very successfully by Japan in its redevelopment after the Second World War. It would be tempting to rely entirely on foreign technology and not bother to do the 2-3% we are able to do on our own. In the forest sector, for the most part, we appear to be doing just that. But to rely entirely on licensed technology is insufficient, particularly for a trading nation--as Japan has realized. If we buy or license, the same technology will be equally available to foreign competitors. And, as tariffs decrease in all regions, there will be increasing pressure to locate production in countries with cheap labor, cheap financing, or cheap resources. The original developer of new technology will seek these countries. This will make it harder for Canadian companies to get early licenses with export potential.

Technology development by Canadian industry is expensive, time-consuming and risky, but the potential benefits are numerous. First, technology development can lead to new, more efficient processes that can lead in turn to cheaper products, for a competitive trading advantage; second, it can lead to unique new products that can be made in Canada and sold abroad, or licensed for manufacture abroad, still producing revenue for the developer; third, even a modest amount of home-grown research can provide a company with the knowledge needed to evaluate foreign research and determine what new developments are most suitable for licensing; fourth, research done at home will provide a product or service that can be a profitable lever of exchange for foreign technology.

The small portion of the world's technology developed in Canada is an essential component in the maintenance of Canada's comparative position as a developed nation. If we allow our research contribution to fall behind the efforts of other nations, our standard of living will inevitably suffer. And yet our research effort is grossly inadequate.

For many years, the federal government has accepted that Canada's performance in research and development has fallen behind that of other developed nations and, in a competitive, technological world, our level of research and development must be increased. The statistics are depressingly familiar. Canada's activity in these areas represents just over 1% of our GDP, while other developed nations have levels of more than 2% and Japan and the United States are aiming for 3%.

Successive governments have pledged to increase Canada's research and development performance to match that of other industrial nations. Success has been very limited to date and, in a time of large deficits, governments are not inclined to prime the pump with more tax dollars.

Nor is the answer reallocation of current funding. In every sector that is capable of undertaking research and development to support economic advance, Canada's performance is very much below that of our major competitors.

Among the 16 leading industrial nations surveyed by the Organization for Economic Development:

Canada ranked 7th in its level of research and development expenditures in higher education, 9th in government laboratories, and, even more important in terms of its direct impact on industrial development, *11th in industry.* [3,4] Every competitor significant to Canada in terms of international trade spent more on research and development than did Canada. Japan's industry spent nearly three times as much as Canada's, as a percentage of GDP. Germany's industry spent 2.7 times as much, the United States spent 2.4 times as much, and the United Kingdom 1.8 times as much. Industry in Switzerland, Sweden, Belgium, the Netherlands, France and Finland all contributed significantly larger fractions of the national GDP to research.

While I can agree that government contributions to research and development should be increased, governments will not make up the shortfall, particularly at a time of large budget deficits. There is here a challenge to the management of Canadian industry to take a long view in the search for productivity improvement and for generation of technology. The management of Canadian industry must commit itself to research and development.

It is here that the Canadian forest industry is failing. According to a recent study for the Ministry of State for Science and Technology, only one forestry equipment company carries out research and development in Canada. The Bioenergy Program, managed by the National Research Council, included the support of mechanical equipment development but this program was lost in the government cuts in 1984. FERIC has recently extended its equipment evaluation program to include forestry equipment development and if this can be maintained it will be a stimulus to Canadian manufacturers. The forest industry as a whole in Canada spends only about 0.3% of its sales on research and development in comparison with the United States and Sweden, where spending is over 0.8%.

In a list of Canadian industries comparing research and development expenditures over the period of 1950-1974,[5] the lumber and wood products industry shared last place with the textile and apparel industry in research and development expenditures as a percentage of sales. Governments (federal and provincial) already contribute about 40% of the total funding for research and development in forest products. In view of the present financial situation, industry cannot expect significant increases in government funding. The government has not written the resource industry off in favor of the space industry, but it expects industry to demonstrate its own commitment to the means for its survival.

Forecasting the future in science and technology is very risky. Professional forecasters are seldom more accurate than science fiction writers in predicting future technology. But the future is clear if the management of Canadian industry, and especially the resource industry, does not demonstrate its commitment to the development and application of new technology.

The challenge to management is especially critical in the forest industry. What is needed is an integrated or "systems" approach to the industry's problems. In a recent talk,[6] a Vice-President of CIP remarked that the Canadian pulp and paper industry urgently needed to develop systems engineers to handle the computerized mill-wide systems that hold the key to cost control. He noted that the Swedish Forest Products Research Laboratory alone employed about the same number of systems engineers as the entire Canadian pulp and paper industry. Further, the systems approach must not be limited to one component of the production process. The system needs to extend from the forest to the final product. The kind of wood, the time of harvest, the method of harvest, as well as the process to be used, will all be affected by the choice of the final product that has been identified as the most advantageous for the world market.

There are three separate, industry-sponsored (with government assistance), forestry-related research institutes--FERIC, FORINTEK and PAPRICAN. There seems to have been little attempt to coordinate their research priorities. Have we looked for the possible relations between the kinds of paper and wood products that Canada will have the best chance of marketing abroad in the future, and the silvicultural requirements and harvesting techniques that would be most appropriate and efficient for those products and timber species? If we had, would one of Canada's largest sellers of wood furniture use Swedish designs made on East German machinery from Russian wood? It may be time to take a new look at the entire system--from forest management to product development.

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3 UNESCO Statistical Yearbook 1985.

4 OECD Selected Science and Technology Indicators 1981-1986.

5 Statistics Canada. Industrial Research and Development Statistics.

6 Globe and Mail Report on Business, 30 January 1986.

The key word is *management*. Management must be convinced of the need to take the long view, the unconventional view.

A recent study by an American management consulting firm[7] reported that:

"Unions are usually blamed for opposing automation, but the true culprit is top management itself. Senior executives are reluctant to take risks or back projects that may not have any payoff until five or ten years in the future."

The introduction of advanced technology to existing industries is not an easy task. Managers of these industries tend to shy away from the effort, sometimes until it is too late. Such industries must, however, learn entirely new ways of doing jobs, they cannot simply substitute new machines for older ones. Such changes require the full cooperation of labor and management, but the onus of initiating the process is on management.

In a recent speech (source unavailable), the president of the Bank of Montreal emphasized the direction in which we must head: "Our prosperity depends most heavily on use of our brains, hard work and the efficient management of labor and capital".

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7 Halbrech Associates Inc., reported in Machine Design, 6 March 1986, p. 4.

The challenge is for Canadian management to increase productivity, to increase the necessary research and development, to introduce new products and processes, not only in the high-tech industries or in the manufacturing industries, which will need to specialize to find their niches in the markets of their industrial competitors, but above all in the resource-based industries of Canada, which provide the trade basis for our current high standard of living, and for which there is no short-term economic alternative.

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MODERN TECHNOLOGY IN FOREST MANAGEMENT— SOME INTERNATIONAL PERSPECTIVES

J.H. Cayford, Director General
Canadian Forestry Service
Great Lakes Forestry Centre
Sault Ste. Marie, Ontario

Abstract.—This paper presents a general overview of the forestry situation in the developing world, with emphasis on the role of trees as a source of fuelwood. Comments are provided on the application of modern technology in forest management and factors that restrict technological advancement.

Résumé.—La présente communication donne un aperçu général de la situation forestière dans les pays en développement et insiste sur l'importance des arbres comme source de bois de chauffage. On y fait des observations sur la technologie moderne appliquée à l'aménagement forestier et sur les facteurs qui entravent son progrès.

Some six or seven months ago I agreed to present this paper on international perspectives on modern technology in forest management. At that time I thought I would develop a questionnaire and distribute it to colleagues throughout the world. On the basis of their replies I intended to prepare a summary on the current and projected use of various types of technology in forest harvesting and renewal, forest maintenance and "high tech" at the desk. This survey would thus have paralleled the organization of this conference and my presentation would have been a list of the various types of technology that will be covered by our speakers over the next three days.

Accordingly, I decided that another approach was required. I intend to present a very general paper that focusses on the developing countries. In so doing I shall leave it to others more qualified than I to discuss technology within their area of expertise.

Of the 4 billion ha of forest in the world, about 50% are in the temperate zone, 40% in the tropical zone and 10% in the arid zone. In addition, there are some 1 billion ha of shrub or woody vegetation that are not classified as forest land. The forests of the tropical and arid zones are under considerable human pressure and are diminishing at a rate of about 11 million ha a year, or 0.6%. The rate of afforestation and reforestation is about one tenth of the rate of deforestation.

There are various reasons for this loss of forest area in developing countries. By far the greatest cause is the widespread clearing of land for shifting cultivation of agricultural crops. In addition, extensive areas adjacent to rural settlements are cleared for anticipated permanent agriculture. These activities are undertaken to meet increasing needs for food, fuel and forage for a rapidly increasing population. One must also note the impact of forest harvesting, without adequate renewal, for industrial use.

The forests of the developing world play a very different role than do the forests of the developed world. In developing countries, forests are most important from a social point of view. They are crucial in rural development, without which there cannot be national development. First and foremost, forests are the source of fuel for warmth, for cooking food, for protection against predators and for lighting after dark. This is in contrast with the developed world, in which most of the forest consumption is for industrial wood.

A recent worldwide analysis conducted by British Petroleum reveals that 34% of the energy currently produced in the world is used by the developing countries, while the remaining 66% is used by the developed countries. However, in the developing countries over 40% of the energy is produced from biomass fuels as opposed to less than 1% in the developed countries. On a global basis, some 54% of harvested wood is used for fuel and approximately 2 to 2.5 billion people, or nearly half of the world's population, depend on wood alone for cooking and heating. It should be noted that this is not expected to change markedly in the near future. To summarize, 80% of the wood used in developing countries is in the form of fuelwood and charcoal: the remaining 20% accounts for all other domestic consumption and for exports.

There is no doubt that there is a fuelwood crisis in many developing countries. In 1981 the Food and Agriculture Organization of the United Nations published a map of the fuelwood situation which was based on an analysis of fuelwood supply in relation to need. Several "situation categories" were established, ranging from a satisfactory situation to one of acute scarcity. Existing situations of fuelwood scarcity involving 100 million inhabitants were identified; a further 1 billion people live in situations in which there are growing deficits and minimum needs are met at the cost of depleting existing resources. Furthermore, it is estimated that, by the year 2000, between 2 and 3 billion people could be facing fuelwood scarcities or deficits.

Currently the situation of acute scarcity is most evident in Africa, especially in the region to the south of the Sahara; other critical regions are in the Himalayas and in arid regions in western South America. Certain regions in Asia (most notably in India, Bangladesh and Pakistan), in the savannah portions of Africa and in semi-arid and Andean parts in South America are currently facing deficits.

Most recent evidence suggests that 63 of the 95 developing countries are already suffering from fuelwood shortages. Of these, 34 have no proven oil or gas reserves as potential substitute fuels.

Numerous reports document the hours required by women and children to collect wood. In some cases up to 40% of the daylight hours have to be spent for this purpose. This situation has a definite impact on the children's schooling and on the housework and farmwork of the women. Fewer meals are being cooked in some African countries; foods requiring long simmering times, such as rice or beans, are being replaced in part by other foods. Fires are quenched immediately after cooking and the embers are saved for the next fire. In towns in which wood is unavailable, costs are increasing and wood may cost more than the food in the pot.

In addition to their importance for fuelwood, forests in developing countries are important as a supply source for small local industries such as furniture, charcoal and basket production. Trees and forests also provide habitat for wildlife and for fish, both of which are important direct sources of food. They also provide such commodities as mushrooms, oils, nuts, fruits and honey, and many other edibles. Even more important is the fact that, in many localities, agriculture simply could not exist without forests, woodlands and trees.

A number of other forest land problems have been caused by unwise agricultural practices. These include degradation of land through soil erosion, sedimentation of dams and reservoirs, and increased flooding of downstream agricultural lands and communities. Also, vast areas of former farmlands have become nonproductive as a result of poor cropping practices and the increasing use of manure and crop residue for fuel instead of for maintaining and improving agricultural soil fertility. A special problem has been created through the expansion of agricultural settlements in areas of low-fertility forest soils.

There is an urgent need in the developing world to manage the forests more wisely and in an integrated manner to ensure that the forests provide a range of benefits. Such stewardship relates primarily to forest conservation and forest renewal, but also to expanding the resource through planting. Forest management must be closely linked with improved and sustainable agriculture and must imcorporate community or social forestry and agro-forestry.

In spite of the fact that tropical forests are being depleted at an alarming rate, there are still extensive tracts of such forests. While some portion might be reserved for natural areas and national parks, most of these forests should be managed. They should be developed for a variety of purposes, including the establishment of new industries (both the traditional forest enterprise type and local industry), the provision of employment and income for rural communities, and the provision of nonindustrial products such as food, fodder and fuelwood.

Having briefly discussed some aspects of the forests of the developing world, I shall now present a few thoughts on the application of modern technology in forest management.

During the 1950s, 1960s, and 1970s the developing world was assisted by a variety of public and private sector international aid agencies. In the forestry sector many aid projects involved the development of large-scale forest industry complexes costing hundreds of millions of dollars and involving the most modern of technology. Some of these projects were successful and have assisted individual countries in developing their forest industry. However, in many instances the projects were not integrated with the rural economy and often the main beneficiaries were the industrialized nations. In some of the projects the main product was roundwood, which was then exported for processing to developed countries.

In more recent years increasing emphasis has been placed on the development of appropriate industry. Under this concept the industry or project is deliberately designed to match more closely the extent and nature of the forest resources with the available management and technical capabilities. Above all, more emphasis is being placed on the involvement of local people in ensuring that they benefit from the development of forest industry.

With respect to social forestry I believe that the use of modern technology will develop slowly in view of the current level of education and training of the majority of people. Participation of the rural population will, in the foreseeable future, be a key component of rural development programs if these are to be successful and are to provide employment and income. Much work in these projects will involve tree planting for such purposes as enhancing food and fuelwood supplies, arresting the development of deserts, restoring soil fertility, protecting against wind and erosion and enhancing water supplies. Nursery production, site preparation and planting will be labor intensive, with minimum application of technology. Tools used will include spades, shovels, rakes, mattocks and wheelbarrows. Normal weed control practices will include hand pulling and cutting.

In developing social forestry programs there is a clear need for forest research. A recent planning workshop organized by the International Union of Forestry Research Organizations (IUFRO) and held in Sri Lanka focussed on the need to increase productivity of multi-purpose trees. One important need foreseen was in tree improvement and propagation, which will require the application of modern technology such as tissue culture, biotechnology and genetic engineering. Research is also required to improve techniques in manual work and to improve or redesign tools and light machinery for different kinds of forest operations.

Forestry as one form of industrial development will continue in some developing countries. In certain projects highly mechanized and sophisticated technology has been developed and is being used successfully, particularly in harvesting and transportation. In contrast, forest renewal, when undertaken, has tended to emphasize manual methods of stock production, site preparation, planting and stand tending. However, in some countries the use of modern, sophisticated and heavy mechanical equipment is gaining popularity, especially for site preparation. Modern remote sensing techniques developed in the industrialized world are being used for forest and land inventory projects in developing countries. Biological control techniques offer opportunities for insect control in plantations in the developing world.

There are, however, a number of basic problems that are holding back or restricting technological advancement in both social and industrial forestry in the developing world. It is conceivable that the wise use of appropriate technology in forestry could be of immense benefit to the developing world, but progress has been painfully slow. Why has this been so? There are a number of reasons:

(1) The uneducated rural population is unaware of the benefits that could accrue from forest management, unaware of the availability of technology, too poor to purchase technology, and not equipped with the basic knowledge and technical skills that we take for granted.

(2) The more educated urban population is unaware of rural problems or unwilling to move into the rural environment.

(3) There is fierce competition for meager resources from the fields of health care and food production, where the demands are more pressing.

(4) There is little time available for forestry. The need for food and shelter is more pressing, and most of the individual's time is spent attempting to meet this need.

(5) There is no immediate return on investments of time or money in forestry.

(6) Cultural and social traditions dictate lifestyle. A prime example is shifting cultivation.

(7) Political instability often creates a poor economic climate.

In Canada we are generally sympathetic to the plight of the developing world. Nevertheless, we are fearful and concerned that these countries have the potential for seriously disrupting the world economy. Does the developing world pose a threat to our forest economy? Can we compete over the long term with countries like Brazil and Chile, with their simpler and less expensive technology, cheap labor, and fast growth? Will our forest industry head in the same direction as our textile, automobile and electronics industries? At present, mahogany moldings and baseboards are cheaper in Sault Ste. Marie than those made from spruce or fir. Similarly, eucalyptus pulp from Brazil can apparently be imported to Terrace Bay more cheaply than pulp can be produced from the adjacent boreal forest. Is this the way of the future?

These are obviously important questions that are being addressed by the forest sector. I think they are important for us to consider in light of the topic of our symposium, "Modern Technology in Forest Management". It seems clear to me that we have a continuing need to optimize the use of modern technology in the forest sector if we are to increase our chances of competing successfully in the world marketplace, in both the developing and the industrial countries. It is to be hoped that the discussions over the next three days will provide some impetus to meeting this challenge.

TECHNOLOGY IN THE NEW FORESTRY AGE: QUO VADIS? AN INDUSTRIAL PERSPECTIVE

M.R. Innes, Manager of Forestry
Abitibi-Price Inc.
Toronto, Ontario

Abstract.--Industrial foresters across Canada were canvassed for their opinion about the progress to date in utilizing technology. A forecast is made of those areas in which technology could be of future assistance in solving the problems of the field forester. The relation between technology and other elements of the practice of forestry is briefly explored.

Résumé.--Un sondage d'opinion sur les progrès dans l'utilisation des techniques a été réalisé auprès des forestiers au service de l'industrie dans l'ensemble du Canada. On donne un aperçu prospectif des domaines dans lesquels la technique pourrait aider le forestier praticien à résoudre les problèmes auxquels il a à faire face. La relation entre la technique et d'autres éléments de la pratique de la foresterie est brièvement examinée.

Primeval improvement: what a title for a symposium on technological advancement! In my mind the word primeval conjures up a picture of evolution from the primordial ooze, or one of antediluvian monsters laboriously dragging themselves out of fetid swamps onto dry land by the use of their semi-articulated bony fins. Surely the forestry profession is more advanced than that, isn't it? Or is it? In order to find out the answers, I talked to industrial field foresters in nine of the provinces. (Prince Edward Island was excluded only because of the scarcity of industrial foresters.) It turned out to be a fascinating exercise and I'm happy to be able to share the findings with you today. I'll leave it up to you to form your own conclusions at the end of the conference about the appropriateness of the word "primeval".

Someone who knows a great deal more about communications than I do once told me that it is possible to transmit only three ideas in the course of a talk. So be it. Here are the three messages, from an industrial perspective.

1. In the past few years we have come a long way in the adoption of technology.

2. The field forester does not see major breakthroughs in technology coming over the horizon in the next two years. Rather, he believes that progress will be made in implementing what is already on the market.

3. Although technology may be of assistance to foresters our most serious problems lie in the fields of policy and administration.

Before I begin embellishing the three messages, I had better address one item that turned up time and again as a source of confusion, and that is the precise meaning of the term "technology". Inasmuch as I have the microphone, we'll use my definition. It is a simple one. Technology is the application of science. A secondary source of confusion that surfaced in conversations with my colleagues was the question of whether we were speaking of new scientific discoveries or (merely) the application of existing science to the field of forestry. Everyone has obviously been brainwashed by the idea that only "high tech" is worthy of note. Here I am discussing both the application of modern technology and the modern application of technology. Both are

useful to our profession. Within this context, I shall present the answers, national in scope, to the four questions I asked industrial foresters. Interest was high and responses usually took about an hour of conversation. Don't forget that the respondents were asked to reply in terms of how the outcome affected program delivery at a field level.

Question number one: "What technological advances have been made in the past five years?"

The answers of necessity reflected the geographic location of the respondent and consequently were dependent to a large degree upon the forest and geography of that location, particularly with respect to their influence on harvesting techniques, silvicultural opportunities and problems, and access difficulties. Consequently, variation was to be expected.

Although they weren't first on everyone's list, computers did surface somewhere in the answer to the first question. What surprised me was the variety of responses. Here is a sampling. One forester thought that ease of access by remote terminal in the field to the mainframe computer was of tremendous significance since it gave him the ability to unlock all sorts of analytical power. Another believed that access to personal computers opened up a whole new world as it freed him from the restrictions of the company mainframe. To one, data processing freed his staff from the drudgery of multiple record entries, while to another, data processing was an evil thing that tied government foresters to their computer stations, thereby preventing them from doing field work and learning whether or not the answers they were generating were meaningful. The increase in available software was commented on--both the canned variety and the programs designed specifically for forestry (e.g., the Canadian Pulp and Paper Association Forestry Computer Applications Survey Compendium now available for use across the country). A geographic information system was an operational reality for one company and was being installed by another. Electronic mail was in effect. Computer simulation of "what if?" scenarios was frequently mentioned. Computerized data collectors for field use in activities such as scaling and plot measurement were high on the list. And there were many other applications too numerous to mention.

Mechanical innovations in harvesting systems were discussed by all respondents. Such things as wide tires, better hydraulics, stroke delimbers, shears, sawheads, lighter grapples, feller bunchers, one-man slashers and grapple yarding were mentioned, and each of these was considered a significant change. A considerable amount of research and technological know-how has gone into the development of hauling systems both in the bush and for highway travel. Such developments have affected not only the weight that can be carried under different axle configurations on the highway, but also road spacing in the woods and the placement of intermediate landings.

Numerous foresters spoke of the interaction between harvesting and silvicultural treatments, and although this may not be a technological change, it certainly is an important spinoff. An interesting concept mentioned by a couple of foresters--one that resulted in greater operating efficiency--was the adaptation of existing harvesting machinery from other parts of Canada to specific conditions in their areas.

Silvicultural equipment also received its fair share of attention. Site preparation equipment was in the forefront. The papers being presented later in this symposium should attest to the progress here. The prevalent feeling was that we were adopting, and in some cases adapting, technology from elsewhere. I'm going to comment on this phenomenon later. A number of people felt that there had been considerable change in nursery management in the past five years. The ability to produce rooted cuttings on a commercial scale was cited as an example. A larger number of species is being cultivated in British Columbia than it was possible to grow previously. Across Canada generally a greater variety of containers is being used in a wide variety of situations. Greenhouse techniques have become more refined, but unfortunately, this has not necessarily resulted in the production of better stock. Alternative methods of growing, such as the "tunnels" (polyethylene hoop greenhouses) used in Quebec, are being explored. Extended greenhousing to produce hardier stock was considered a useful innovation.

Mill changes were mentioned as well. Twin-wire paper machines, computer-controlled paper machines, and the use of pelletized fuel as well as wood for fuel were all discussed. An Alberta respondent stated that one of the most significant technological changes in his area was the development of an oriented strand board process that used poplar. Hardwood utilization was having a signficiant impact on forestry programs in that province.

The foregoing is a random sample of the answers I received when I asked foresters what they considered the most important technological advances in forestry over the past five years. I hope you will agree with me that considerable progress has been made in the adoption of technology.

Question number two: "What advances will be made in the next two years that will affect you and/or your company?"

I got a bonus here because I really received two different responses to my question: an implicit response and an explicit one. The detailed replies dealt with what was already on the market but had not yet been implemented by the company for which the respondent worked or elsewhere in the area. I'll tell you about them in a moment. Beneath the surface, however, I detected a reticence to acknowledge significant technological breakthroughs as a continuing possibility, and I was left with the suspicion that foresters are not aware of what is happening at the edges of technological development.

From the replies I received, I concluded that most foresters do not think there will be a lot to cheer about in the next two years. With one exception (an imminent retiree) the respondents were looking forward to either the installation or the refinement of a geographic information system. Most had high expectations of relational data bases. The consensus was that a new era of forest planning would be possible. Several touched upon the interface between a geographical information system (GIS) and the data necessary to run it, and looked to a better means of collecting data directly in the field and electronically dumping them into the system.

The hope was expressed that advances would be made in the development of pesticides, but the respondents had no specific knowledge of the areas that would likely change. Continual evolution in harvesting and silvicultural equipment would occur but no one could offer an example of what might happen. Ever-increasing specialization was considered likely. The word "refinement" was used frequently. When questioned specifically about the possibility that remote sensing would be more widely applied at a field level, all respondents replied that it was not likely.

We obviously do not have great expectations. It certainly gives one cause to wonder why.

Question number three: "What areas are the most likely to receive attention because of a need for technological assistance?"

In other words, where are the gaps? This question yielded a more interesting collection of responses. At this point everyone fell off the technology wagon and told me ALL his problems, both science-related and otherwise. Only with difficulty could I drag the conversation back to technology. Anyway, here is a sampling of the replies I received.

Perhaps the most logical way to collate the responses is to proceed from seed to tree to harvest to planning. Tree improvement was a favorite topic. It was felt that selective breeding to produce those wood properties required for specific end uses should be undertaken. Genetic engineering to provide for herbicide resistance, disease resistance and insect protection was considered necessary. No one was happy with the quality of nursery stock, irrespective of the origin of stock or province of residence. All felt that some improvements had to be made in calibrating a nursery system to the site so that the seedling could be produced to maximize both survival and growth on a specific site. Would it not be possible to build in a better system of slow-release fertilizers? Was tissue culture for mass propagation a realistic hope? The problem of frost hardiness has been with us since the beginning of time: wasn't that a little long to go without resolution?

Site preparation was too drastic a method of preparing the ground for the next crop. Could there not be some type of system that would favor seedling growth yet discourage non-target species? Why wasn't there a planting machine that could be used in bush operations? Pruning was a terribly laborious method of improving quality. Could it be streamlined? The same question was raised about thinning in more than one province. Nearly everyone wanted to see more work done on herbicides. Would it be possible to develop a biological herbicide? The lack of silvicultural techniques that could be applied in winter was seen as a major problem by many respondents.

Forest resource inventory methodology was considered woefully inadequate by one respondent. This tied in well with the desire of several foresters to be able to make better use of remote sensing techniques. Why wasn't better resolution possible from Landsat? Better methods of predicting insect epidemics were needed so that treatments could be applied before the insects got out of control.

Harvesting came in for suprisingly few suggestions. How to deal efficiently with small, patchy timber in low-volume concentrations was a problem. What could be done to

design a steep-slope logging system that could operate in volume conditions normally associated with eastern Canada? Were better systems available to harvest insect-damaged wood without breaking it? Equipment was needed to work on more varied terrain. The availability factors of mechanical equipment could be substantially increased.

The largest segment of the wish list dealt with the need to present an integrated picture of what was happening in all areas of forestry. Many identified the gap in growth and yield information and some went further to decry our inability to construct models that could be used to make sophisticated long-range forecasts. Where was the economic modelling that would help to determine justifiable levels of silviculture expenditure? Where were the site-related support models on which to base silviculture decisions? Integrated resource management was not a reality and a great deal of hard data was required before meaningful monitoring could be undertaken. Should not someone be working on quantifying productivity gains to be realized under various integrated systems of harvesting and silviculture? I'm sure that by now you have a feeling for the way the conversations went.

The foregoing comments had to be distilled from a much more detailed conversation that dealt with the need for tenure; the difficulties of working in a system that is governed largely by political decisions (or a lack thereof until it is too late); the problem of explaining forestry to a public that is uninterested until misinformed by environmentalists; and the pitfalls encountered in trying to convince senior management that intricate planning is mandatory despite its high costs.

Question four: "Are there any impediments to the adoption, adaptation or implementation of technology?"

This time the answer was simple. It was "no". There was no resistance to technological change among workers at any level. I found this somewhat surprising. Of course, there was a right way and a wrong way of introducing change and I heard stories of each. Of all the success stories, my favorite comes from my own company at Pine Falls, Manitoba. Here a computerized parts inventory system was designed and installed with the able assistance of all the garage staff. The fact that it works is readily evidenced by the thick layer of grease on the PC terminal keyboard and the fingerprints all over the screen!

As I mentioned at the outset of this paper, I found the variety of answers to these four questions fascinating. In the remainder of this paper I would like to pass on to you some of the more cogent comments that were not in direct response to the foregoing questions.

The use of technology in manufacturing processes in the forest industry is evident. It is less evident in harvesting and woods operations, and is just barely evident in forest renewal operations. This is a curious phenomenon and one that is well beyond the scope (or purpose) of this paper. The fact that we are investing in our mills means that there isn't a cash flow problem. Yet we have not convinced--have we tried?--our leaders to invest in the bush. I suggest that it is time we attempt to make that bush-mill link.

Another area of concern arose in the discussion of technology. Past practice has been to install the latest technology in the mills for a higher-quality product with less variation and, in the process, to use fewer people. In the minds of the majority, the invasion of "high tech" has meant staff reductions. This is a bit frightening to industry foresters who have just been through the most severe staff cutbacks since the Depression. Consider the following "dog chases tail" syndrome. The use of technology increases efficiency, thereby decreasing staff, and consequently the remaining staff members are under pressure to handle a greater range of jobs that they never have time to learn properly, and are thereby forced to seek more technology to increase their efficiency to reduce the pressure...etc. As one forester put it, "There is always some priority other than learning; you are left to do that on your own time and initiative". Those of us who are managers must face this problem squarely.

It came through time and time again that we are applying science to our problems on a piecemeal basis. Someone said that we have been project-oriented. There is a great need to be able to link the market-driven demand all the way back to silviculture and to do it in such a way that we can budget for the entire procedure. If we do not, we may just find that silviculture will be too expensive to practise in Canada.

Policy and administrative problems were considered by respondents to be so pervasive that they by far outweighed problems related to lack of technology. I do not find it irrational for the forester in Saskatchewan to focus his attention entirely on persuading politicians to permit him to use the chemical

herbicides registered for forestry use in Canada--herbicides that are used every day by farmers--rather than worry about how to use satellite imagery. Most of the respondents considered the need for general forestry education in the schools to be far more important than the need for technology.

Most people felt that because forestry was such a young science in this country, we had not done nearly enough to improve current practice. Basic information is not being shared coast to coast and significant gains can be made, especially in silviculture, merely by implementing what works elsewhere. Never forget that forestry is both an art and a science and the art of forestry is improved only through constant practice and refinement. The temptation is great to throw new technology at problems that are local and pressing but have been solved elsewhere.

Science is an integral part of the forest industry at all levels of operation. There is an urgent need to increase our application of science in forestry if we are to continue to compete in international markets. However, I am inclined to share the view expressed in the recent report of the Science Council of Canada that scientists and engineers (including foresters) do not feel confident about Canada's capacity to exploit new technologies. We have instead adopted what works in some other area or country. Sometimes we have been sufficiently brave to adapt as well as adopt, but the pace of change has been slow.

Technology isn't something that is forced upon us. Rather, it is something we all should be clamoring for, seeking out in other fields, and directing our scientists to produce. We need it to solve problems, to integrate currently disparate segments of resource management, to remove drudgery and to free time for meaningful work, to increase our access to knowledge, and above all to reduce costs.

I came across a quotation the other day that I felt was appropriate to this conference. The famous author George Bernard Shaw once said: "The reasonable man adapts himself to the world. The unreasonable man persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man."

It is clearly up to us to take Shaw's dictum to heart and to be unreasonable in our efforts to find, adapt, adopt and implement technology so that progress can occur.

One last thought: There will be no "quick fix" as a result of the sudden transfusion of "high tech" alone. Technology must operate in tandem with coherent policies in the business, manufacturing and forest management fields. It's going to be fun: let's get on with it!

MODERN TECHNOLOGY IN THE FOREST SECTOR: A FEDERAL PERSPECTIVE

J.C. Mercier
Associate Deputy Minister (Forestry)
Canadian Forestry Service
Ottawa, Ontario

Abstract.--From a federal perspective, the theme of modern technology is particularly timely for the forest sector. At a time when the need for technological innovation in order to maintain competitiveness is of major concern, Canada's forest sector, however wrongly, is perceived as non-innovative and traditional, in effect, a "sunset" industry. If this is true, the decline of the sector is inevitable. If it is only partly true, the perception is nonetheless very harmful and must be changed. Canada's forest sector has been innovative and must become more so. Further, it must be seen to be so by competitors, partners, and the public.

Résumé.--Du point de vue fédéral, le thème de la technique moderne est particulièrement opportun en ce qui concerne le secteur forestier. À une époque où le besoin d'innovation technique est de première importance pour maintenir le pouvoir concurrentiel, le secteur forestier du Canada est perçu, à tort ou à raison, comme traditionnel et peu inventif, c'est-à-dire une industrie arrivée à son crépuscule. Si c'est vrai, son déclin est inévitable; même si cette perception n'est fondée qu'en partie, elle est néanmoins très dommageable et doit être modifiée. Le secteur forestier du Canada s'est révélé innovateur et doit le devenir encore plus; en outre, il doit être perçu comme tel par les concurrents, les partenaires et le public.

I am very pleased to be here today to present to you a federal perspective on the theme of modern technology in the forest sector.

This is indeed a most timely theme. The Wright Report, the Nielsen Task Force, the Technology Centre Policy, the Forestry Forums, the National Forest Congress, and most recently, the speech from the throne, have all emphasized this theme. They all allude to the danger of Canada's losing its technological edge. All note the low level of investment in research, development and innovation in Canada. All are calling for improved and more effective use of scarce research resources through industry, university and government collaboration.

We are the world's leading exporter of forest products but our competitive edge is being threatened by nations that can grow and process trees more quickly, efficiently and cheaply. Consequently, many outsiders perceive Canadian forestry as ultraconservative and lacking in innovation. Forestry is perceived as a "sunset" industry by many decision-makers.

If this perception is correct, the sector is truly doomed to decline. If it is incorrect, as I believe it is, the perception is nonetheless very harmful to the forest industry and to the Canadian economy. We cannot afford either the reality or the perception of being a sunset industry. The forest sector must not only be innovative but must also be

perceived as such by other sectors and by the public. Only then will the forest sector be considered a target for research and development strategies, a suitable and responsive context for the development of saleable applications and systems incorporating the new technologies, and a desirable partner and participant in advanced technology consortia.

The sector certainly is large enough to stimulate and support research, development and technological innovation. Forest management spending almost doubled over the period 1977-1983, from $700 million to $1.3 billion. Since 1984, through a series of five-year forest renewal agreements, the federal government and the provinces have increased fourfold the level of funding for forest renewal. In harvesting and processing, capital investment is expected to reach $50 billion between now and the year 2000.

Applications of technology are scarcely new in the Canadian forest sector. We have already demonstrated that we can produce state-of-the-art forest technology that others want to acquire or adopt. The Dipix satellite image analysis system has worldwide application in forestry. The University of British Columbia's Forcyte forest growth and yield simulation model is now in use in various private and government agencies in the United States and a dozen other countries, and development is continuing on a newer version of the model. Incidentally, one of its principal developers, Dr. J.P. Kimmins, recently won a IUFRO Scientific Achievement Award.

The Petawawa National Forestry Institute (PNFI) has developed several models for forest fire management systems that are now being used successfully in Canada, the United States and China.

We also have FIDME (Forestry Investment Decisions Made Easy), a flexible model used to compare long-term forestry investment alternatives. Because it can be programmed to handle elements of variability and probability, it can be used to account for risk and uncertainty associated with long-term investments. Over two dozen Canadian and American computer systems now have it and the Great Lakes Forestry Centre is developing a version of it for microcomputer systems.

Canada is not in the Japan-United States microchip league, and is therefore unlikely to produce new technology with applications in many fields. What we can do and do well in forestry is provide a creative, innovative and stimulating environment for the development of applications and systems in areas such as biotechnology, advanced forest management and protection, information management systems, and industrial process control systems.

In biotechnology, for example, there are three major research areas we should address: the production and protection of trees, bioconversion and biocontrol, and biopulping and waste treatment.

In the field of production and protection, we can examine the cloning of elite trees and families of trees to provide the maximum exploitable genetic gains in the least time. We can introduce, through genetic engineering, new genetic information in our tree improvement and breeding programs. We also have opportunities to develop biologically based herbicides by exploiting the abilities of various pathogens.

As for bioconversion and biocontrol, much forest-produced biomass currently has little or no industrial use. But from a chemical perspective, it may be possible to produce a range of products from forest biomass, such as resins, plastics, phenols, surfactants and adhesives. In addition, we may be able to use antagonistic organisms for wood protection and preservation.

In the realm of biopulping and waste management, research results indicate that considerable energy savings are possible through the microbial pretreatment of chips used for pulping. Research is also under way on the detoxification and recovery of spent liquors from the pulping process through microbial action.

With respect to information management and artificial intelligence, we can refine and extend systems such as the Forest Fire Command Centre technology, now in operation in Maniwaki, which is being transferred to Quebec and Ontario. Expert systems to support decision-making through information evaluation and forecast modelling could have major impacts in forestry in fields as diverse as growth and yield, harvest planning and disease control. The use of geographical information systems to store, integrate and retrieve in usable form the immense quantities of forest data is essential to modern forest management. New remote sensing systems such as the extremely effective Multispectral Electro-optical Imaging Scanner (MEIS) illustrated in the PNFI poster display at this symposium beg to be integrated as data acquisition tools into such systems. The opportunities to develop saleable or tradeable technology are enormous.

In the areas of harvesting and processing, process control systems and, to some degree, robotics should be particularly fruitful subjects for research, but this opportunity to develop saleable technology in order to avoid importing it is not fully exploited. While the industry is certainly large enough to support such research, the use of "in-house" research capacity and the mobilization of capacity existing in universities, the National Research Council (NRC) and the computer industry appear limited. Perhaps a cooperative approach involving the forest sector, advanced technology and equipment supply companies would be more productive. Most definitely, this is an area in which industry must take the lead.

We must not forget that research, however ingenious, however perceptive, cannot solve problems unless the forest sector as a whole perceives that it has problems, that it has a major responsibility to solve those problems and that it must deliberately create a "technology pull"[1] environment.

In this context the federal government, particularly the Canadian Forestry Service (CFS), has a major role to play, one that I will describe briefly. First, the CFS has the federal government's mandate as the key agency for innovation, research and development in forestry. To carry out that mandate, we have 825 person-years and $68 million in the current fiscal year.

We have two strong "in-house" research programs in forest management and protection. As you already know, we are providing leadership in the application of computer technology to forest management planning and timber harvesting. Our researchers also have solid experience in bacteriology and virology that enables them to take the lead in cooperative work with their colleagues at NRC and the universities, and permits the CFS to serve as the coordinating agency in developing the knowledge needed by industry to make and market better biotechnology-based insecticides.

As well, the CFS supports research into methods to increase the competitiveness of the Canadian forest industry. In 1986-1987, the CFS will contribute $1.6 million to support the Forest Engineering Research Institute of Canada in its attempts to improve harvesting methods, transportation of wood, and mechanization of silvicultural operations. We also share 50% of the cost of FORINTEK with industry and the provinces to ensure research into better forest products.

Over the life of the current federal-provincial forest renewal agreements, the CFS and the provinces will provide about $30 million over and above the amount allocated to continuing programs for research, analysis and technology transfer.

This year we are providing $6 million to support university research and student employment in research. However, we will soon transfer this responsibility to other agencies that are more directly related to pure research and job creation such as the Natural Sciences and Engineering Research Council (NSERC), NRC and the Canada Employment and Immigration Commission.

There are other federal agencies that will support forestry research. NRC has its Pilot Industry Assistance (PILP) and Industrial Research Assistance (IRAP) programs. NSERC has a program of university support and the Department of Supply and Services has its program to entertain unsolicited research proposals, while the Department of External Affairs has its International Research Development Centre.

In recognition of the growing trend toward trade protectionism and the increasing competitiveness of other forestry nations, the CFS is enhancing its capability in research on forest economics and trade. We are also developing a closer working relationship with the Department of External Affairs as the government evolves a continuing strategy to deal with bilateral and multilateral trade issues as they arise.

In total, the federal government's research effort in forestry is quite large, but by itself it is not adequate to meet all the research needs of the forest sector.

We can provide research leadership, as well as continuity, support and communication links for research programs. We can also provide, within reason, mission-oriented research programs, particularly in the areas of forest management and protection, to bridge the gap between the initial knowledge-seeking research, the later developmental research and finally application.

However, there is an overall scarcity of research resources. It is essential that we have participation by and collaboration between research agencies and their clients. That is why we in the CFS welcome the recent

[1] "Technology pull" refers to a situation in which potential users of a given technology are urgently trying to draw upon research organizations to obtain it.

statement of the Canadian Pulp and Paper Association in which it cites the need for increased industrial participation in research. Following a review of the current situation by the Forest Research Advisory Council of Canada, the Honourable Gerald S. Merrithew, Minister of State for Forestry and Mines, identified this subject for future discussion by the Canadian Council of Forest Ministers.

In this context the Council will soon launch a National Forest Awareness Campaign in cooperation with the provinces. The main goals of the campaign will be to demonstrate the importance of the forest sector to the Canadian economy, and to obtain widespread public recognition of and support for the government's commitment to the continued growth of this sector.

The dual message about the forest sector that must be conveyed to Canadians concerns its beneficial effect on the economy and its increasing technological capacity.

In conclusion, I wish to emphasize that the forest sector, if it is to survive, let alone prosper, must commit itself fully to innovation and the adoption and adaptation of new technologies in all areas from forest genetics to product development. Concerted action by all parts of the sector is essential.

Since the forest sector is unlikely to develop basic technology in areas such as electronics and biology, it must be highly creative, receptive and effective in incorporating innovations in these areas into systems that will be of significant value to forestry, so that eventually it can export, or at least trade, rather than import technology.

Finally, these attitudes must be communicated to potential collaborators and to the public if the sector is to be targeted or even considered in the development of research strategies, in the application of new technologies or as a useful member of the technology community.

The alternative is to make the "sunset industry" prophecy self-fulfilling.

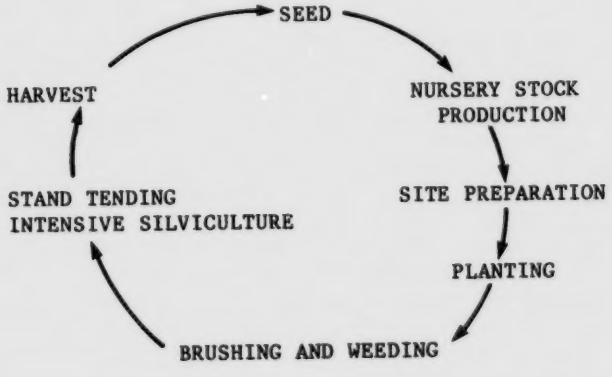
PRESENT AND FUTURE OF SILVICULTURE IN BRITISH COLUMBIA

C.M. Johnson, Director
Silviculture Branch
British Columbia Forest Service
Victoria, B.C.

Abstract.--The British Columbia Forest Service operates under a Five-Year Forest and Range Resource Program, which requires the production of 241 million plantable seedlings by 1988. This paper outlines the Five-Year Silviculture Program and some of the current and probable future trends in silviculture activities in British Columbia, particularly in seed production, nursery seedling methods, planting contracts and brushing and weeding activities.

Résumé.--Le Service des forêts de la Colombie-Britannique réalise ses activités dans le cadre d'un programme quinquennal relatif aux ressources des forêts et des parcours prévoyant la production, d'ici 1988, de 241 millions de semis prêts à planter. Le document décrit le programme quinquennal de sylviculture ainsi que certaines tendances actuelles et futures des activités sylvicoles en Colombie-Britannique, notamment en ce qui concerne la production de semences, les méthodes de production de semis en pépinière, les contrats de plantation ainsi que les activités de badigeonnage et de désherbage.

From my perspective, the present and future of silviculture must be reviewed as they relate to the silviculture chain of events. This chain of events can be called the silviculture circle and each item in the circle is intimately related to the others.



In British Columbia, we have a well developed seed program for the production of both natural and orchard seed. We have recently completed construction of a new seed center at Surrey under the Canada-British Columbia Forest Resource Development Agreement (FRDA) at a cost of $3,000,000. With the installation of a new Hillishog seed processing line we are anticipating the production of higher quality seed to improve nursery production.

We have made significant progress in our tree improvement-seed orchard program. Since 1979, we have established the coastal and interior tree improvement councils, with representatives from 23 forest companies, the University of British Columbia, the Canadian Forestry Service and representatives from the British Columbia Forest Service (BCFS). Since 1978, over 4,435 and 3,792 parent trees have been selected in the coastal and interior programs, respectively. As of 1986, there are 33 intensively managed seed orchards spanning 108 ha in the province. Nineteen orchards (totalling 48 ha) are managed by forest companies through credits to stumpage under section 88 of the Forest Act and eight orchards (totalling 16.7 ha) are privately funded. Over the next 10 years, a further 80 ha of orchards

will be established: 40 ha will be managed by the Forest Service and 40 ha by the forest industry.

Seed production of 600 kg in 1983 and 154 kg in 1985 from seed orchards has been impressive. At present, there is a seed inventory of 25 million potential seedlings from orchard seed produced in 1983 alone.

In British Columbia, we have been fortunate that our early researchers established a number of excellent provenance and progeny trials for Douglas-fir *(Pseudotsuga menziesii)* [Mirb.] Franco), lodgepole pine *(Pinus contorta* Dougl.), interior (white) spruce *(Picea glauca* [Moench] Voss), and Sitka spruce *(P. sitchensis* [Bong.] Carr.). These studies have been exceedingly valuable in our tree improvement program: they have been useful both in the development of the breeding program and in the establishment of time frames within which improved breed stocks may be developed. Provenance and progeny test data have been reviewed to make recommendations on new seed transfer rules for interior spruce, lodgepole pine and coastal Douglas-fir.

We foresee two major future developments in seed production: the development of potted seed orchards in greenhouses and the implementation of a seed sorting process (IDS)[1] for improving germination rates for individual seedlots. This year (1986) we began pilot operations with potted seed orchards for both interior spruce and western hemlock *(Tsuga heterophylla* [Raf.] Sarg.).

The British Columbia nursery program has expanded enormously in the last seven years. A $30,000,000 increase in the province's silviculture budget was recently announced and we shall sow for 241,000,000 seedlings in the spring of 1987. At present, BCFS produces 100,000,000 seedlings and the other 141,000,000 seedlings are produced in six forest company nurseries and 18 corporately owned commercial nurseries.

Nursery production methods have changed considerably in the last five years. With bare-root seedling production, we are concentrating our efforts primarily on Douglas-fir and lodgepole pine, which are all precision sown. Container styroblock production accounts for 85% of all nursery production and is used to grow all species. In the last two years, our nursery growers have begun a huge 2-0 container program mainly for interior spruce but also for western red cedar *(Thuja plicata* Donn), western hemlock and Douglas-fir. This stock type is replacing bare-root transplants (particularly interior spruce transplants) in a large way. Considerable savings have been realized, as 2-0 containers cost 16.8 cents apiece in comparison with 30-35 cents apiece for bare-root transplants. The 2-0 containers are grown in a number of ways, but most are either grown in outside compounds for two years or else started in greenhouses and then moved outside. The main problem with this crop is overwintering. We are working on a number of methods to prevent overwintering losses. With 2-0 container crops grown on the lower mainland and Vancouver Island, our overwintering problems are minimal.

With our normal 1-0 container program, we have considerably improved our sowing dates and have found that earlier dates mean a better-quality product. We are also paying much more attention to the analysis of nutrients in foliar tissue in an effort to establish a good base line for referring to this analysis as well as a better understanding of the nutrient status of our seedlings. Nutrient analysis of tissue must be done on a regular basis to correct problems and provide indicators of developing seedling problems before they become visible. In addition, we are attempting to automate the extraction, culling and packing processes of our container program; we anticipate prototyping an automated extraction process by July 1987.

As you can see, our nursery technology has changed rapidly in the last 10 years, and we expect that this trend will continue. Cutting culture will develop rapidly in nursery systems, and the transplantation of mini-containers into larger containers will be mechanized. The nursery business today involves the handling of large amounts of material and consequently a great deal of capital is tied up. New directions must be carefully planned so that, as biological changes in the process occur, we can continue to utilize the materials handling processes we have developed.

The next link in the chain is site preparation. In British Columbia, we need to strengthen this activity considerably so as to improve forest yields. With our interior spruce progeny test program, 15 years of growth data have demonstrated that height growth of white spruce planted in a marginal ecosystem with good site preparation was 19% better than that of white spruce in a good spruce ecosystem with poor site preparation.

Prescribed burning continues to be our main site preparation technique on 43,000 ha and, in my opinion, many of our best established, free-growing plantations are on sites prepared in this way.

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[1] incubation, drying, sorting

Various methods of mechanical site preparation for both natural and artificial regeneration are used on 44,000 ha. Particularly in the Prince Rupert and Prince George regions, mounding techniques have improved growth performance of spruce plantations considerably, because increased soil temperatures have meant good initial root establishment and the inverted mounds and double humus layer have increased nutrient supply.

The BCFS has prototyped a new mounding machine to make optimum use of some of these biological principles. We anticipate developing three of these machines in 1987 for operational work, particularly on the wetter, colder spruce sites.

I predict that we will eventually see much more intensive mechanical site preparation and, in some cases, double site preparation. Site preparation helps to improve planting accessibility and reduce planting costs. With prescribed burns, we shall have to consider every available window to do the job and burning decisions will be made on the basis of objective indices to achieve the goals we set for each burn.

In British Columbia, our main concern is the sheer size of our planting program and the number of workers required to implement it. In the two northern regions we had the planting window reduced by 2 weeks last spring because of a late season, and we had considerable difficulty obtaining sufficient contractors and planters. As planting programs accelerate in Quebec and Ontario, fewer planters from those two provinces are heading west.

We are considering a number of ways to improve this situation:

1) a summer planting program with 35 million 2-0 spruce container seedlings (not lifted) on moist, fresh sites in the two northern regions. (This will greatly expand our planting season.)

2) classifying our contractors in one of three categories: A, B, or C. (The best [A category] contractors will put down only 5% deposits, while B and C category contractors will be required to put down 10%. We believe that this will encourage our A class contractors to expand their businesses.)

3) new 3-year planting contracts and multi-phase contracts, which should increase the stability of the British Columbia silviculture contracting community

With our planting program, we have developed a good planting quality-inspection payment system. If planting quality falls below 85%, the contractor receives no payment.

Researchers in British Columbia have demonstrated the advantages of fertilizing at time of planting, and development trials have been conducted over the past 2 years. Many problems have arisen in the application of fertilizer to planted seedlings as a separate operation, and I believe that we must look at long-term, slow-release fertilizers to alleviate these problems. The BCFS intends to provide direction in this area.

We must also develop more and better planting machines for sites on which machines can be used. From studies done by Dr. Thomas J. Smith, Professor of Kinesiology at Simon Fraser University, it is evident that we must pay more attention to the ergonomics of planting.

The BCFS has laid the foundations for an excellent ecological classification program. This system has major implications for proper species selection and should lead to significantly increased yields in the province over a rotation. High-quality training of silviculture personnel in ecological interpretations is very necessary.

With the implementation of a 241,000,000 planting program in 1988, the province will reach its desired goal of a steady-state silviculture program in which 75% of our logged lands will be restocked artificially.

Our new basic silviculture goals for the province of British Columbia, for all activities, are presented in Table 1.

Table 1. Basic silviculture goals (figures in '000 ha).

	1985-1986	1986-1987	1987-1988	1988-1989	1989-1990
Surveys	360	360	360	360	360
Planting	91	109	130	161	161
Site preparation	110	125	136	136	136
Brushing and weeding	14	20	40	50	50

The other weak link in the silviculture chain in British Columbia is the brushing and weeding Program. Since planting began in 1939, over 1.2 billion seedlings have been planted on over 1 million ha of land; an appreciable portion of these areas has been affected by brush competition, especially on the most productive lands. Stands that were well stocked have been reduced to the not satisfactorily restocked (NSR) category. Valuable plantations have been converted into brush fields consisting of varieties of vegetation complexes.

Our current estimate of areas invaded by brush indicates that a significant proportion of the province's most productive sites have some brush problems. About 500,000 ha of backlog and current NSR areas need some vegetation control. Nearly half of this area (237,000 ha) requires immediate vegetation management or the young conifers will be lost. Brush areas in all inventory groups total about 2.9 million ha. At the current rate of annual forest depletion, over 48,000 ha are expected to be added annually to the existing brush areas in the province unless proper management is undertaken. This figure represents about 25% of the total area harvested annually. On the basis of the mean annual increment for unmanaged forests in British Columbia, the total potential annual losses at rotation in these areas have been estimated at 8.2 million m^3 of wood, or enough wood for 15,000 houses--$52.1 million in stumpage and $637 million in shipment value.

In British Columbia, we continue to emphasize that good site preparation techniques and high-quality planting stock can do a great deal to minimize the loss of plantations to brush. Foresters must also be able to use herbicides as one of their main vegetation management tools. We believe that we must educate and inform the public, and encourage more involvement in this important area of forest management, if plantation investments are to be protected.

We are very pleased that, with the recent increase in silviculture financing by the British Columbia government, we will be able to increase our brushing and weeding efforts from 20,000 ha in 1986 to 40,000 ha in 1987 and 50,000 ha in 1988.

In the intensive silviculture Program we have spent considerable time delineating the size of backlog NSR lands and the opportunities those lands present. Intensive silviculture treatments include the rehabilitation and restocking of backlog lands and the improvement of immature forests through spacing, fertilizing and conifer release.

Intensive silviculture activities are expanding rapidly under the FRDA, as efforts are made to meet silviculture goals (Table 2).

In the backlog program we have identified 737,900 ha of NSR land on good and medium sites that require treatment (Table 3). Our intensive silviculture backlog planting program will rehabilitate 20% of these idle forest lands in the next 5 years.

It has been estimated that renewal of the 737,000 ha of backlog sites will create 10,000 person days of work for each $1 million of direct expenditure. This is only the beginning as these lands are estimated to be capable of producing 143 million m^3 of harvestable wood. Even with employment ratios substantially below those of the forest industry at present, the rehabilitation of these lands will provide 125,000 person-years of work in logging and wood processing. The annual wood yield will increase by 1,750,000 m^3, enough to support over 1,500 high-paying jobs indefinitely.

Table 2. Intensive silviculture goals (figures in '000 ha).

	1985-1986	1986-1987	1987-1988	1988-1989	1989-1990
Surveys	100	166	167	167	167
Backlog planting	16	20	36	36	36
Site rehabilitation	20	35	36	36	36
Brushing and weeding		2	6	6	6
Spacing		5	16	20	19
Fertilization		9	20	19	18
Conifer release		1	2	3	3

Table 3. Total area in the "not satisfactorily restocked", "disturbed stocking doubtful" and "noncommercial brush" categories on crown Land, tree farm licences and timber licences (figures in ha).

	All sites		Good and medium sites only	
Forest region[a]	1979	1984	1979	1984
Cariboo	174,400	158,900	110,400	100,800
Kamloops	150,400	193,600	107,000	141,000
Nelson	262,800	244,000	174,200	156,800
Prince George	823,700[b]	2,142,800[c]	292,400	632,700
Prince Rupert	419,100	703,000[b]	98,500	120,300
Vancouver	94,300	111,500	80,500	77,600
Total before factoring*	1,924,600	3,553,900	864,000	1,229,200
Total after factoring*	1,095,200[d]	1,634,500	655,600	737,900

*Totals may not be precise because of rounding

[a] The regional data are gross inventory figures before regeneration factors were applied to allow for expected natural stocking.

[b] The large increases in Prince Rupert and Prince George result from more detailed surveys in remote northern areas. Over three-quarters of the increase is in poor and low sites.

[c] Prince George figures for 1979 included some Peace River data that had already been factored.

[d] Reflecting minor 1982 adjustments.

In British Columbia there has been increasing interest in intensive silviculture as a generator of employment. In addition to the FRDA funding, $20 million has come from the provincial Forest Stand Management (FSM) fund, and federal funding under make-work programs has amounted to $4,480,000 in fiscal 1986-1987. To date, $12 million from the FSM fund has been used to put social assistance persons to work in intensive silviculture. We anticipate that the government will continue to expand this program, and we hope to integrate the workers eventually into British Columbia's active silviculture contractor community.

In the intensive silviculture program much more economic analysis is necessary so that we can determine our investment priorities. Along with greater economic input, our growth and yield data base must be greatly improved, because such data are essential for sound economic analysis.

I would like to comment briefly on our efforts in forestry research. The state of research is probably best reflected in a statement extracted from a document (title unavailable) prepared by the British Columbia Forest Research Council: "For the period 1975-82, total research expenditures in the province for all agencies on forest research has averaged 0.28% of the value of forest products manufactured and 0.137% of the gross national product. Nationally, forestry R & D expenditures are less than 0.7% of forest product sales, which compares unfavourably with those for USA 1.5% and Scandinavia." In view of the increased investment in silviculture and the importance of forestry to Canada, it is mandatory that our forest research efforts be increased.

In British Columbia, the silviculture field offers many opportunities and challenges for the future. There are numerous weak links in the silviculture chain of activities, and these must be strengthened. It will take the combined efforts of all agencies to make this business grow and thrive.

FOREST HARVESTING AND RENEWAL

REVIEW OF CURRENT USES AND TRENDS IN MECHANIZED SITE PREPARATION TECHNOLOGY APPLICABLE TO ONTARIO CONDITIONS

C. Rodney Smith, Head
Mechanization of Silviculture Unit
Canadian Forestry Service
Great Lakes Forestry Centre
Sault Ste. Marie, Ontario

Abstract.—Current uses and trends in mechanical site preparation technology in Canada and elsewhere that are relevant to Ontario are examined. Key factors influencing these trends are reviewed. Site preparation operations included in the review are vegetation removal/control, slash treatments, blade scarification, disc trenching, cone head scarification, mixing/tilling, spot scarification, mounding and plowing.

Résumé.—Les faits et les tendances dans la préparation mécanisée du sol, tant au Canada qu'à l'étranger, et qui intéressent l'Ontario sont examinées ainsi que les facteurs déterminants de ces tendances. Les opérations à l'étude sont l'élimination et la maîtrise de la végétation, le traitement des rémanents, la scarification (au moyen de lames, de fraises coniques, par placeaux), le tranchage à disques, le travail et le mélange du sol, l'aménagement de buttes et le labour.

INTRODUCTION

Mechanical site preparation technology plays an important role in the overall forest management program in Ontario. In fiscal 1985-1986 nearly 100,000 ha were site prepared in Ontario. Mechanical site preparation accounted for 84% of the total.[1] Elsewhere in Canada, comparable percentages for fiscal 1982-1983 were 30%, 100%, 80% and 66% for British Columbia, Alberta, Quebec and New Brunswick, respectively (Kuhnke and Brace 1986). The mechanical site preparation program has doubled in size in Ontario in the last decade and has increased steadily since fiscal 1981-1982, with roughly 90% of the area planted and seeded in recent years being mechanically treated.[1]

[1]Anon. 1986. Silvicultural Information Systems (SIS), Table 1, Reports 1975/76 to 1985/86. Ont. Min. Nat. Resour., For. Resour. Br., Toronto, Ont.

CURRENT USES AND TRENDS IN ONTARIO

The number of models of skidder-drawn disc trenchers and patch scarifiers on the market has been increasing. However, the northern Ontario market for such machines has not been large. In a region with 24 Ontario Ministry of Natural Resources (OMNR) districts and 27 Forest Management Agreements (FMAs), if one excludes equipment leased from distributors, only 39 trenchers and patch scarifiers have been purchased since 1979 (Table 1). As for other types of equipment, the number of shear blade and Young's Teeth implements appears to be increasing. Although their use is on the decline, many heavy drag implements remain on inventory. There are very few plowing, drainage, tilling and chopping implements.

Table 1. Estimate of northern Ontario site preparation equipment inventory, 1979 and 1986.

	1979[a]			1986[b]		
	OMNR owned	FMA owned	Contractor or rental agency owned	OMNR owned	FMA owned	Contractor or rental agency owned
Plows						
Marttiini	3			4		*
Struik Arch Plow	1			1		
CFS Row Scarifier	1			1		
Discs/Disc Plows						
TTS-35	11		*	17	3	*
TTS-35H/Delta				1		
TTS Delta Powered				2	1	3
Donaren 180-D Powered						1+*
TTS-10 Mini				1		
Eden Relief-V Disc Scarifier						1
Cone Head Scarifier						
GLFP Powered Head Scarifier					2	
Drags						
Barrels, chains, etc.	many			many	some	
Scalpers/Patch Scarifiers						
Bräcke 2-row	14		*	11	8	1*
Bräcke Badger (3-row)				7	2	1*
Bräcke Herbicider				3		*
Leno Scarifier	2			3		*
Blades/Blade Attachments						
Young's Teeth (sets of 2)	44		*	56	1	*
Rome K/G Shearblade			*	3	5	8
Beale Shearblade				1		
Fleco Shearblade				1		
C&H Plow	6			4		
CFS V-blade	2			1		
Blades/Blade Attachments						
Fleco V-blade				2		
V-blade--various models	many			18	3	
Malan Slash Divider				1	2	
Skidder Slash Estimator				1		
Root (Rock) Rake	**			11		
Eden Rake				2	1	*
Raumfix				3	1	*
Tillers/Shredders						
Madge Rotoclear						1
Choppers						
Fleco Chopper				1		
Marden		1		1	1	*
Other						
Flail Scarifier	1			1		

* Leased units available from distributors.
** Unknown.
[a] Primary source Smith (1980).
[b] Dominy, S.W.J. 1986. Data from Ont. Silvic. Equip. Ref. Cat. update.

FMA holders are carrying out 37% of the site preparation work in Ontario[2] and 53% is done by private contractors[3] who also do part of the work on the FMAs. Since 1979, the FMA holders and contractors have accounted for approximately half of the major new equipment acquisitions (Table 1). Spinoffs from the FMAs include ready access to mechanical support facilities and skilled staff knowledgeable in current off-road technology (Smith 1984). This should foster the application of at least harvestingequivalent technology in silviculture. Union-ized labor on FMA operations may demand more ergonomically suitable equipment and working conditions in the future. Contracting fosters competitiveness and low costs in the short term. However, the practice of annually tendered contracts causes financing difficulties for small contractors and does not promote the acquisition of newer, more advanced technology (Ryans 1986a).

Harvesting practices have a major impact on site preparation operations. Full-tree harvested area increased steadily from 16.3% in 1980 to 30.7% in 1984 (Anon. 1986). The relatively slash-free, full-tree logged sites are more easily treated with lighter implements. This, combined with a trend to earlier post-harvest treatments, is resulting in increased use of lighter implements.

The utilization of hardwoods on mixedwood sites remains a problem. Heavy equipment, expensive to operate, is often needed to treat sites with hardwood residuals. Local and regional markets for hardwood are growing in some areas but there appears to be no clear trend toward increased hardwood use in Ontario (Anon. 1984), although the potential exists since aspen (*Populus* spp.) is considered the best species for the emerging hardwood paper technologies.[4]

Because of reduced oil prices the potential for reducing slash and vegetation backlog problems as a consequence of using forest biomass for energy is low. A limited amount of equipment is available or is under development for use in such applications, e.g., the prototype Crabe Combine brush harvester based on the Finnish Pallari concept but redesigned by the Canadian Forestry Service to suit Canadian conditions (Sutherland 1985). Prolonged high prices in the future might stimulate more activity in this area.

A policy of prime site management could also stimulate interest in dealing with backlog on prime lands as well as an increase in intensive site preparation and tending treatments.

DIRECTION OF EQUIPMENT DEVELOPMENTS IN SCANDINAVIA

Sweden and Finland continue to be leaders in mechanized silviculture. Berg[5] states that the present trend in Scandinavian equipment is toward scarifiers that can be adjusted according to the site, i.e., single machines able to mound, patch and furrow with work controlled from the driver's cab. Fryk (1986) states that it should be possible to operate machines both intermittently and continuously (as in the case of the Waddell-Fräsen Scarifier described herein), and to achieve different results by varying the unit's contact time, pressure and angle, and pattern of movement. Development is proceeding by combining two different machines into one (e.g., the TTS Combi [see "Plowing"]) but mainly by creating "variation units" in which a single unit operates in different ways (e.g., the Marttiini Multipurpose AKIM 190 plow [see "Plowing"]). Ideas being tested in 1986 include the use of an intermittent mode on disc trenchers and the creation of mounds by forcing discs to work from side to side or by changing the contact angle cyclically. There is potential for computerized control systems with this type of equipment.

REVIEW OF CURRENT EQUIPMENT APPLICATIONS AND DEVELOPMENTS IN CANADA AND ELSEWHERE

Clearing of Brush and Trees

In Ontario, mechanical clearing of brush and trees has generally involved the use of bulldozer front-mounted or drawn implements. Mechanical treatments often include slash disposal and soil cultivation and may be used alone or in conjunction with herbicides and/or prescribed fire. Although a wide array of powered cutting/mulching equipment is available (McKenzie and Zarate 1984), e.g., Hydro-Axe Rotary Head Cutter, these machines have a high energy requirement and function poorly on rocky terrain; consequently, their use is limited to specific situations.

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[2]Tworzyanski, T. Quoted in Wood, T. 1986. The art of rebuilding forests. Landmarks, summer issue. p. 28.

[3]Anderson, M.E. 1986. Ont. Min. Nat. Resour., For. Resour. Br. (pers. comm.)

[4]Styan, G. 1986. The economics of growing wood in northern Ontario. Remarks to 1986 Annu. Meet., OPFA, Sudbury, Ont.

[5]Berg, S. 1986. Forskningsstiftelsen Skogsarbeten, Spanga, Sweden. (pers. Comm.)

With the exception of brush harvesting and other harvesting equipment, there has been no significant advance in vegetation-clearing technology in the past 5 years. A newer concept that may have some application in brush clearing is the front boom-mounted 1.5- to 1.7-m-wide cutting disc available on the Shar 20 tracked carrier manufactured in the United States and the Canterra CT-268 brushcutter (wheeled carrier) distributed by Canterra Engineering Limited, Calgary.

Reduction or Redistribution of Slash

In northern Ontario, slash has been dealt with primarily in single treatments combined with scarification and/or competition removal. Mechanical treatments to remove slash only have not been common.

The most significant advance in slash raking technology in the past 5 years has been the development of flexible tooth rakes. These rakes have teeth that swing or slide out of the way and then back in place when meeting firm ground and obstacles. This permits more or less continuous forward motion and minimal soil disturbance. Slash piles are relatively dirt free and easy to burn. Models are available for both skidders and crawler tractors. These rakes are designed to clear slash, not to scarify, although for certain prescriptions the degree of disturbance possible may be adequate.

The Raumfix slash rake available from Afortek and Canadian Forestry Equipment in Canada has teeth that slide mechanically up and down on the front of the blade. The Eden piling rake is manufactured by Cazes and Heppner Forest Services Limited of British Columbia. Teeth swing back under the blade and are hydraulically sprung. The FORCE Sitemaster slash piling rake is manufactured in the United States and is similar to the Eden.

Comparative trials of the Eden and Raumfix were carried out in Ontario in 1982[6]; the Eden (2.4 m and 3.7 m models), the Raumfix and an agricultural root rake were compared in Newfoundland in 1984[7] and in 1985 and 1986, the FORCE and Raumfix were compared in Quebec[8]. Many recommendations for modification of the rakes and for their application have resulted from these trials and other operational experience (e.g., Coates et al. 1984).

Blade Scarification

Blade-type implements such as straight blades, Young's Teeth and shear blades are simple and reliable, bulldozers are readily available, and there is sufficient power to clear slash, brush, stumps and residuals while exposing mineral soil or shearing away surface organic layers. Consequently, these tools will be used in Ontario for many years. However, because their application is highly operator-dependent, results can be inconsistent and the degree of disturbance excessive (Smith 1980, Puttock and Smith[9]). Also, blading may reduce fertility and productivity is low.

The most recent attempts to improve upon blade-type implements include the Fesco V-plow manufactured in the United States. The Fesco has a double-moldboard plow configuration with depth control provided by two vertically adjustable skid plates located at the nose. Although the site-prepared area of the largest current model is too narrow (0.9 m) for two planting rows[10], it remains an efficient V-blade concept with good flotation characteristics on certain sites.

Disc Trenching

The Finnish TTS-35 Mechanical Disc Trencher, available from KBM Forestry Consultants Inc. and Hakmet Limited, has been used in Canada since the early 1970s. Some of the more relevant and/or recent literature on

[6]Anon. 1983. Evaluation of the Eden SRK-880 piling rake and Raumfix 4 slash piling rake. Ont. Min. Nat. Resour., Blind River, Ont. Intern. Rep. 22 p.

[7]Brake, R.J. 1985. Slash raking: a site preparation technique. Dep. For. Resour. and Lands, St. Georges, Nfld. Intern. Rep. 35 p.

[8]Jeanotte, M. and Beauchesne, C. 1986. Préparation de terrain utilisation des rateaux FORCE et Raumfix. Min. Energ. Ressour., Rég. Abitibi Temiscamingue. Rap. No. 821-85200. 36 p. + append.

[9]Puttock, G.D. and Smith, C. Rodney. 1986. Evaluation with Young's Teeth on sites with dense residual poplars. Gov't of Can., Can. For. Serv., Sault Ste. Marie, Ont. (in prep.).

[10]Leblanc, J-D. and Sutherland, B.J. 1986. Comparative evaluation of seven site preparation tools in a residual poplar mixedwood stand in Saskatchewan. Gov't of Can., Can. For. Serv., Sault Ste. Marie, Ont. (in prep.).

its use includes McMinn and Homoky[11], Smith (1980), Coates and Huessler (1984), Smith et al. (1985) and Leblanc and Sutherland[10]. Though not yet tried in Canada, a recent innovation of the TTS-35 has been the addition of hydraulically controlled wheels for use in transport and in maneuvering. Also available is a scaled-down version, the three-point hitch farm tractor-mounted TTS-10.

The Finnish MM Disc Scarifier/CFE Scarifier, available from Canadian Forestry Equipment Limited, has been recently introduced to Canada. It is much heavier than the TTS-35 (3175 kg vs 2025 kg).

Second- and third- generation disc trenchers under development since the 1970s (Berg 1981) and used operationally in Scandinavia for some time have overcome many of the shortcomings of the mechanical units. Developments in this area are as follows.

The TTS-35H and the newer TTS Delta Disc Trenchers have passive discs mounted on independent, hydraulically controlled arms. Down pressure adjusted from the cab controls digging depth. The discs can be lifted for maneuvering and transport. The disc angle can be adjusted manually. Hydraulics can be provided by the skidder. Units have been used in seven provinces in Canada. Trial results of the TTS Delta have been reported by Williams[12], Hedin (1985) and Sidders[13].

The TTS Delta Powered Disc Trencher has the same features as the Delta, plus hydraulic rotation of the discs. Units have been used since 1985 in New Brunswick, Quebec, Ontario, Manitoba and Saskatchewan. Trial results are limited[14].

The Swedish Donaren 180D Powered Disc Trencher was the first powered unit introduced to Canada (in 1981). Distributed by Canadian Forestry Equipment Limited, it has the same basic features as the TTS Delta Powered Disc Trencher. Units are in use in Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia. Trials have been reported by Berg and Jonsson (1981), Ryans (1982) and Puttock and Smith (1986).

Units not yet introduced to Canada include the Swedish FIAB MB-25 powered disc trencher. A four-row FIAB Quattro is under development (Samuelson 1986). Passive disc models are available. The Swedish Murveln powered disc trencher has particularly long, aggressive teeth. The TTS-35 HJ Disc Tiller has relatively flat discs with less aggressive stud-like teeth that rotate at 40 rpm (vs 20 rpm for the Delta Powered). The TTS-50 4HJ Multi Disc Trencher has four discs, each on independent, hydraulically controlled arms. Two passive leading discs push slash and duff aside. Two rear powered disc tillers form a berm. Auxiliary engines are required for the last three units.

Specialized powered discs are used on the Finnish Serlachius (Tetra) automatic tree planter marketed by Equipment Denis of Quebec. Two flat, toothed discs are mounted in front of each of the rear bogey wheels of the forwarder. Planting heads are located behind the wheels. Results of trials in Finland are summarized by Stjernberg (1985). Trials were conducted in Quebec in 1985[15] and 1986[16].

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[11]McMinn, R.G. and Homocky, S.G. 1975. Biological effectiveness of equipment tested in silvicultural-mechanical site preparation trials. Dep. Environ., Can. For. Serv., Victoria, B.C. Prelim. Rep. Exp. Proj. 741. 40 p.

[12]Williams, D.R. 1984. The TTS Delta Disc Trencher: Quality of scarification, productivity and costs as experienced by Houston Forest Products Company. Houston Forest Products Ltd., Houston, B.C. 26 p. (unpubl.).

[13]Sidders, D. 1986. TTS-35 Delta field trials. Ont. Min. Nat. Resour., Dryden Distr., Dryden, Ont. Intern. Rep. 20 p.

[14]Harrow, A.E. 1985. Site preparation with the TTS-Delta with powered discs. Ont. Min. Nat. Resour., Northeastern Region, Sudbury, Ont. Intern. Rep. 8 p.

[15]Arsenault, J. and Brunelle, A. 1986. Rapport sur les essais de la planteuse TETRA. Min. Energ. Ressour., Rég. Bas St. Laurent-Gaspésie, Unité 13, Baie-des-Chaleurs, Qué. Intern. Rep. 68 p.

[16]Coté, B. and Gendron, N. 1986. Essai de la planteuse méchanique de plants en contenants, "TETRA" dans le Grand-Portage (1985). Min. Energ. Ressour., Rég. Bas St. Laurent-Gaspésie, Unité 11, Grand Portage, Qué. Intern. Rep. 23 p.

Mechanical disc trenchers like the TTS-35 are simple to use and maintain and are easily mounted on readily available skidders. For this reason they will be used in Canada for some time. The second- and third-generation down pressure and powered head units have a wide range of adjustments that are made rapidly and, with their aggressive action, more severe slash (Berg 1986) and duff conditions can be handled than with the mechanical units. Hence, more varied or more consistent results can be achieved. The major disadvantages of the more sophisticated disc trenchers and other powered head units are the higher capital cost (including the cost of modifications to the prime mover), the lack of suitable prime movers and the added complexity (Ryans 1986a). Despite these disadvantages, it is expected that the market for these implements will grow steadily in the near future.

Trials of the TTS-35, the TTS Delta Powered Disc Trencher, with and without power, and the Donaren 180-D in Saskatchewan in 1986 should provide an indication of the relative advantages and disadvantages of these tools under Canadian conditions.

Cone Head Scarification

The cone head scarifier has a studded, cone-shaped working head that is rotated against the direction of forward travel. In milling machine-like fashion, surface material is scalped away and pushed to one side. The cones tend to burrow beneath slash as opposed to rolling over it as discs tend to do. There are two types of cone head scarifiers at the present time.

The Swedish Wadell-Fräsen Scarifier has two independent arms, with rotational speed (0-30 rpm), angle towards the surface and down pressure of the cones controlled from the cab. Operation is continuous or intermittent. Power for the implement is provided by an auxiliary engine. A trial was conducted in Quebec in 1986.

The Wadell-Fräsen is used on the Swedish Silva Nova automatic tree planter. Cones are placed behind the rear bogey wheels in front of the planting dibbles. Results with this unit are summarized by Stjernberg (1985).

The Great Lakes Forest Products (GLFP) Powered Head Scarifier was developed by GLFP and Northern Engineering and Supply Company of Thunder Bay in 1983. It was designed for use on a converted Koehring KH3B Shortwood Harvester. Four cone heads similar to those of the Wadell-Fräsen are mounted on independently controlled arms. Staff of the Great Lakes Forestry Centre completed an evaluation of a unit in 1986.

High-speed Mixing/Tilling

The most significant application of high speed mixing/tilling in Canada has been with the Madge Rotoclear. Manufactured by Can-A-Mex Manufacturing Limited, Calgary, it is tractor drawn and has a 2.3-m-wide drum with replaceable teeth that turns up to 360 rpm. Designed for preparing range land in the prairies it has been used in Ontario for reclaiming farmland and for specialized applications such as seed tree orchard establishment. Besides having a high energy requirement the Madge is highly sensitive to rock and therefore is not operationally suitable for many sites.

McMinn (1985a) reports long-lasting increases in growth of white spruce *(Picea glauca* [Moench] Voss) on fine-textured soils in British Columbia as a result of mixing with a Madge Rotoclear versus screefing. Trials have also been conducted recently in New Brunswick and on prime lands in Ontario.

Spot Scarification and Mounding

The Swedish Bräcke Cultivator distributed by KBM Forestry Consultants has been used in Canada since the early 1970s. Some of the more relevant and/or recent discussion of its use is found in McMinn et al. (1975), Smith (1980), Berg and Jonsson (1981), Coates and Haeussler (1984), Smith et al. (1985) and Leblanc and Sutherland (1986)[10].

The Swedish Leno Patch Scarifier arrived here in the late 1970s, and is distributed by Canadian Forestry Equipment Limited. Relevant and/or recent literature on the Leno includes that by Berg et al. (1981), Coates (1984), Smith et al. (1985) and Leblanc et al. (1986). Lighter and more maneuverable than the Bräcke, the Leno is less aggressive and therefore does not penetrate slash and duff as well as the Bräcke.

The versatility of the Bräcke has been increased. The Bräcke Herbicider is the same basic unit equipped with a sprayer. The Bräcke Badger has an extendable drawbar permitting five row and spacing combinations of the machine frames. These settings combined with variable within-row spacing and scalp length can produce a wide range of results permitting preparation for planting or seeding. Theoretically, the three-row, 2-m Badger

can increase production by 50% over the regular two-row/2-m unit. Results of trials in Canada are reported in Ryans (1986b).

Favorable results have been reported from mounding in Sweden (Edlund 1979) and British Columbia (McMinn 1985a). However, as with other treatments, mounding is a species- and site-specific technique. For example, planting of jack pine (*Pinus banksiana* Lamb.) produced better results on the shoulder of the unmodified Bräcke patch in boreal Ontario than on simulated mounds (Sutton 1984).

The Bräcke Mounder is designed to produce mounds in a two-stage process. Hydraulically operated scoops placed behind the mattocks on a regular two-row Bräcke dig mineral soil from the previously scalped patch and deposit it on top of the inverted mound created by the mattock. Since 1983 the Mounder has been used in British Columbia, Saskatchewan, Ontario, Quebec and New Brunswick. Trials of the Mounder in British Columbia and recommendations for modifications are reported in Brewis (1984), McMinn (1985b) and Parolin[17].

The Sinkkilä Mounding Spot Scarifier has been used in Finland for many years. More recent models have two sets of mattocks with 80-cm-long tines. A self-contained hydraulic system locks and releases the mattocks. Controls are mounted in the cab. Because of the length of the tines a relatively deep scalp can be dug and an inverted mound created. Heavier slash can be penetrated than with a Bräcke or Leno. Six units of a newer model, Sinkkila-2, were in use in Finland in 1985[18]. A unit was brought to Canada in 1986 by Canadian Forestry Equipment Limited for trials in British Columbia and Alberta. A lighter Sinkkilä-3 model is under development in Finland[19].

The British Columbia Forest Service's prototype Spot Mounder was a single-stage hydraulically controlled scoop. The Mounder is mounted on the parallelogram of a D7 tractor, and a slash divider is required to clear slash. Progress on the unit is reported in Brown (1985). Further work is required to design a lighter, more compact machine.

Plowing

Though never undertaken extensively in Canada, most tractor-drawn, moldboard-type plowing on forest cutovers has been done with the Finnish Marttiini Plow. The principal advantages of the Marttiini include its rugged design and ability to treat sites with a high water table and very thick organic matter (Smith 1980, Coates and Haeussler 1984).

The newer and more versatile AKLM-190 model (not yet used in Canada) has a hydraulically controlled pivot in the "goose-neck" that gives more control over the plowing action, i.e., from a deep, V-furrow to a shallow, flat-bottomed furrow. With the plow point raised, extendable screefers on each side of the wings create two continuous furrows.

The TTS Combi Trencher has a plow and wheels similar to those of the Marttiini, and two discs similar to those of the TTS Delta. It is designed for areas in which discing and plowing are desired but the use of two separate implements is uneconomical. It has not yet been introduced to Canada.

SUMMARY AND CONCLUSIONS

The dependence on mechanical treatments should continue in the future, although fire and herbicides are likely to be used more extensively. The flex-tooth rakes, hydraulic disc trenchers, cone head scarifiers and Bräcke Badger are indicative of the highest level of technology being used in mechanical site preparation in Ontario, i.e., sound, innovative engineering with, in some cases, widely used industrial components, but none of this can be considered "high technology". Previous technology lagged far behind that used in the logging industry; however, some of the machines in use in Ontario today employ harvesting-equivalent technology.

The trend in Ontario to full-tree harvesting and to earlier post-harvest treatments is resulting in a greater use of light, skidder-drawn implements. Powered implements such as the disc trenchers are likely to proliferate because of their ability to produce consistent results and to work in more severe conditions. The demand for prime movers that are suitable for use with hydraulically powered implements will grow. A small

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[17]Parolin, R.W. 1986. Upper-halfway trials of Bräcke Mounder. Consultant's Rep. 15 p.

[18]Appelroth, S.-E. 1986. For. Res. Inst., Helsinki, Finland. (pers. comm. with J. Gomelski, Leningrad, USSR)

[19]Appelroth, S.-E. 1986. For. Res. Inst., Helsinki, Finland. (pers. comm.)

demand for "silviculture-only" prime movers is likely. The need for heavy, blade-type, bulldozer implements to treat sites with heavy slash, backlog and dense residuals will continue. A policy of prime site management could stimulate a need for intensive site preparation and backlog treatments. It is unlikely that slash and backlog problems will be significantly reduced for some time as a result of the demand for energy from forest biomass.

As in the past, the leading edge of relevant mechanized silviculture technology is in Scandinavia where the trend in development is toward single site preparation machines with the ability to treat a variety of site conditions, e.g., by producing a variety of microsite types. Simple multi-function machines such as the Bräcke Herbicider have been developed as well as far more complex site preparation and planting machines that could be easily equipped with pesticide and herbicide applicators. The latter have yet to be proven operationally and economically.

What about future technology? Computers are now being used directly in the most sophisticated tree planters to coordinate ground sensing and planting functions. It is conceivable that simple computer-controlled ground sensing devices for site preparation operations will be developed. As with other areas of forest management, mechanized site preparation operations will benefit indirectly from the use of computers, e.g., by better utilization of increasingly available site-specific information in the setting of prescriptions. Remote video to monitor and adjust working heads is a possibility. Lasers? They are being used now in agriculture to control spacing. Electronic navigational systems referenced to satellites? This too, is a possibility.

Although mechanical site preparation has never been in the forefront in the development or utilization of modern technology, there is no doubt that the level of technology used in this area will improve.

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PRESCRIBED BURNING

P. Gagnon, Fire Operations Officer
Aviation and Fire Management Centre
Ontario Ministry of Natural Resources
Sault Ste. Marie, Ontario

Abstract.--Wildfire is a natural component of the environment of the boreal and, to some degree, of the Great Lakes-St. Lawrence forest regions. Controlled fire (prescribed burning) is man's attempt to use this natural phenomenon to achieve his forest and fire management goals and objectives. In Ontario each year approximately 250,000 ha of forest land are harvested. Through the use of prescribed fire a significant portion of this area can be safely, effectively and economically treated for subsequent regeneration of the land base. The acceptance, understanding and application of technological improvements are essential to the development of prescribed burning as a key tool in future forest management in Ontario.

Résumé.--Le feu de friches est un phénomène naturel dans les forêts boréales et, jusqu'à un certain point, dans celles de la région des Grands Lacs et du Saint-Laurent, tandis que le brûlage dirigé (contrôle) constitue, en quelque sorte, l'équivalent dont l'homme se sert pour atteindre ses objectifs d'aménagement forestier et de lutte contre les incendies. En Ontario, environ 250,000 hectares de forêts sont exploités chaque année. Le brûlage dirigé permet le traitement sûr, efficace et économique, en vue de la régénération d'une part importante de cette superficie. Il est essentiel d'accepter, de comprendre et d'appliquer les progrès techniques pour que le brûlage dirigé devienne un outil majeur d'aménagement forestier en Ontario.

Between 1966 and 1976 the province of Ontario averaged approximately 20 prescribed burns totalling 1900 ha annually. From 1977 to 1981 the average had increased to 30 burns per year on 3100 ha, and from 1982 to 1984 there were over 40 burns on 5700 ha. During the last two years, Ontario's prescribed burn program has expanded dramatically.

In 1985, 43 burns were carried out on 10,635 ha, and with the 1986 season nearing completion, 14,223 ha have been treated successfully in 56 burns.

These steadily rising figures are a result of the increasing demands of forest managers and the development of expertise among fire managers, as well as the conviction on the part of both parties that prescribed burning is a useful management tool. In addition, both the technology and the funds necessary to achieve results have played a key role in Ontario's expanding prescribed burn program. Technological developments in prescribed burning have been particularly successful in the areas of ignition and weather.

Until the mid-1970s Ontario relied on hand ignition to execute a prescribed burn. Various systems were in use, from dropping matches to using drip torches and flame throwers, such as the Fedco Model T. Although they are still employed on prescribed burns, they are generally reserved for small burns or as a "touchup" in strategic areas of a larger burn.

Prior to 1974, aerial ignition in Ontario was confined to a few adventurous people using small helicopters and flare pistols or hand-dropped fusees. These initial attempts were not considered successful because there were safety and ignition problems. As a result of discussions with an Australian fire researcher on loan to the federal government in 1973, the idea of mass ignition was introduced in Ontario. The Australians were at that time dropping vials containing potassium permanganate injected with ethylene glycol (anti-freeze) from an automatic dispenser on board a fixed-wing aircraft. After experiments with a hand application of this principle, the decision was made, early in 1975, to proceed with the development of an operational system for Ontario. With the assistance of the Equipment Development Section of the Alberta Forest Service and the Pacific Forest Research Centre (now the Pacific Forestry Centre), the Ontario Aerial Ignition Device (OAID) was designed, developed and available for operational use by 1978. Although the device was initially considered for use with wildfire only, the prescribed burn program eventually shared the benefits of this much faster, safer and cost-efficient ignition system.

Although the helitorch, or "flying drip torch", was first developed in the early 1970s by John Muraro of the Pacific Forest Research Centre, the early torches merely dripped raw petroleum fuels over the burn site. These fuels were ignited at the torch tip by an electrical arc or, in an improved design, by a propane flame.

The original torch concept was greatly improved by the development of fuel-thickening compounds that gelled the fuel, thus reducing its volatility. This development increased the safety of fuel-handling procedures, improved the drop characteristics of the fuel, put more fuel onto the ground (rather than burning it off in the air), and increased its residual burning time on the ground.

In 1983 Ontario began extensive testing of three helitorch systems: the Okanagan, Simplex and Northern Mountain helitorches. After a thorough 2-year evaluation, the Simplex Helitorch Model 5400, made by the Simplex Manufacturing Company of Portland, Oregon, was chosen. It was given one more year of operational testing on prescribed burns, and with planning and operational guides in place, is now used across the province.

A few examples of situations favoring the use of both the helitorch and the OAID are given below (Springer and Ward 1986).

The helitorch has proven to be more beneficial than conventional ignition systems in a number of burn applications, such as the following:

1) on sites with sparse or patchy fuel distribution (The pattern of fire laid down by the torch can provide a better chance of ignition than the OAID, because with the latter, many balls may fall onto areas of sparse fuel, causing a delay in developing a complete fire line.)

2) on sites with abundant green vegetation, extensive wet areas, or other fuel discontinuities (Again, the pattern of fire laid down by the torch and the fuel's residual burning time on the ground aid in developing a continuous fire line and achieving a more complete burn. On one burn done on typical clay belt sites in the Kapuskasing District both the helitorch and the OAID were used; the portion ignited showed more complete ignition and better achievement of the prescription.)

3) ignition of aerial fuels such as standing timber, blowdown, or poorly tramped fuels (Aerial ignition devices tend to fall through to the ground where there may be inadequate fuel conditions to carry the fire.)

4) where the intense ignition pattern of the torch can result in a more quickly established convection column.

Some very general guidelines are offered below for situations in which the OAID might be preferred to the helitorch. This is by no means an exhaustive list. The fire manager must rely on his own experience and determine the requirements of the particular burn when selecting a system.

1) Burns in which, because of size, poor access, etc., the fixed costs of helitorch operations (mixing crew, fuel, fuel delivery) may result in a higher cost per ha.

2) sites with adequate, evenly distributed fuel that can be ignited easily by aerial ignition devices

3) prescribed burns in which time limitations favor the quicker setup possible with the OAID

4) burns on which long ignition lines can be flown without returning to the staging area

5) understory burns, in which the burning gelled fuel of the helitorch would ignite the canopy.

In the near future both of these aerial ignition systems will play an integral part in Ontario's prescribed burning program. Continuing improvements to both systems, in areas such as mixing, and research designed to achieve understanding of the effects and behavior of fires set according to these two mass ignition systems will ensure their efficient use for years to come.

After a successful field demonstration in LaSarre, Quebec of a torch designed for ground application of gelled fuels, Ontario will be conducting operational trials of two similar systems. Both the Boise Interagency Fire Centre's Terra Torch and the Chemonics Torch will be field tested for potential use in the prescribed burn program, as well as in wildfire situations.

With respect to safety and efficiency, all of these ground-gelled torches are deemed to have great potential for the ignition of slash piles, especially those vast piles remaining from mechanized full-tree harvesting operations. With a range of over 30 m it may well have other fire management uses as well.

Two other systems now being tested in the western United States are designed for cost efficiency and safety in areas with steep terrain. They also make use of the opportunity for night ignition and better control of the overall ignition pattern. Under development since 1981, the Laser Ignition Device (LID) is not meant for actual ignition of the forest fuel but for activation of a squib that is an electrical ignitor. The laser itself does not require any great intensity, but only a specific frequency for detonation. This in turn ignites a fuel that could be anything from bags of gelled fuel to thermite cord. Multiple ignition can be carried out by simply running parallel electrical lines between the fuel cells or by using thermite cord. Other methods being tested include radio control, aerial application of the LID, and a mortar-type delivery system for ignitors such as the potassium permanganate and ethylene glycol used in some aerial ignition devices. Printed results are not yet available, but R.E. Johnson[1] of the USDA Forest Service in Washington state advises that laser ignition devices are both accurate and cost efficient, and have unlimited potential for use in wildfires and prescribed burns.

The ignition of forest fuels with a CO_2 laser has been tested in Australia for over 5 years. Waterworth (1983) describes the system's advantages and some of its technical aspects. Improved safety, control and mobility, as well as low cost, are mentioned. Waterworth[2] could provide me with no additional details at this time because an international patent is being sought. He did say that the first commercial prototype of the LID will be demonstrated in Australia in February 1987, and in the United States and Canada starting in April.

Initial investigations of laser ignition have also been carried out in Canada by AASS Aerospace Inc., under the sponsorship of Environment Canada. This work was directed at the laser ignition of arctic marine oil spills. The investigators have since met with representatives of Environment Canada's Environmental Protection Service, the Canadian Forestry Service (CFS) (including the Petawawa National Forestry Institute), and fire managers from the province of Quebec. A study was carried out by the CFS to determine the feasibility of using lasers for prescribed burns across Canada[3]. The present paper provides only a general overview of ignition systems, but demonstrates how the expansion of technology in this area has aided immensely in Ontario's growing prescribed burn programs.

Accurate, reliable and timely weather data have been cited by many as the key to providing both accurate burn results and information on whether the prescribed burn can be conducted safely under present and forecasted weather conditions. Such data also supply answers to questions concerning fire control, behavior and intensity, since atmospheric conditions affect smoke dispersion, spotting potential and fire intensity.

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[1] Johnson, R.E. 1986. Remote ignition system. USDA For. Serv., 13 p. (unpubl. rep.)

[2] Waterworth, M.D. 1986. University of Tasmania, Hobart. (pers. comm.)

[3] Higgins, D. and Ramsay, G. 1986. Update on laser ignition of forest fuels. Gov't of Can., Can. For. Serv. (unpubl. rep.)

As early as 1978, the province of Ontario started using a computer weather program (PBWX) developed by D. Martell of the University of Toronto, for planning burns. With this program the forest manager and fire manager can determine, from historical records collected at 130 weather stations across Ontario, the number of potential burning days available, i.e., once a prescription burn has been determined and the subsequent fire indices are developed to meet that prescription, PBWX is accessed to determine the number of days per month that one can expect those parameters to be available. The program also assists the fire manager in determining the probability that the desired conditions will occur and in selecting the season best suited for the burn. The system is continually updated and used for all prescribed burn planning in the province. Weather technicians were introduced to the fire management program in the late 1970s and now all five fire regions as well as the Aviation and Fire Management Centre have the use of their valuable services.

Environment Canada's Atmospheric Environment Service (AES) has been providing special forecasts for prescribed burns since the mid-1970s. These forecasts are prepared by meteorologists who use all available data, including actual observations of temperature, relative humidity, windspeed and wind direction collected from many Ontario Ministry of Natural Resources' (OMNR) sites. Upper air data, on the other hand, are collected at only a few sites in Canada and the United States. For example, three sites in Ontario, one in Manitoba, one in Quebec and two in the United States provide for twice-daily measurements of upper-air parameters such as pressure, humidity, temperature, windspeed and wind direction. These observations are taken at 08:00 and 20:00 hr E.D.T.

As the majority of prescribed burns are ignited between 13:00 and 18:00 hr, the atmosphere below 2000 m undergoes rather large diurnal changes in value. For this reason, and because data on distances must be extrapolated from the permanent sites, OMNR has acquired minisondes to provide more site-specific measurements of upper air data in terms of stability and wind profile. The system used at present consists of six major parts: the airborne radio transmitter with integrated temperature sensor, the balloon and filling system, the minisonde receiver and processor, the printer, the balloon tracking theodolite, and the Sharp 1500A hand-held computer. The total initial cost is approximately $17,500 Cdn, and each ascent costs approximately $25.00 Cdn.[4]

The airborne minisonde transmitter measures and transmits a continuous temperature signal throughout its ascent. This signal is received and recorded as a continuous temperature trace on the recorder chart. From this temperature trace the following information can be calculated: degree of atmospheric stability, heights and strengths of inversions, maximum afternoon temperatures, minimum afternoon humidity, and heights of upper-fronts.

The balloon theodolite is used to track the balloon visually in free flight. The azimuth and elevation angles are read and recorded manually at intervals of more than one minute. From these angles the following information is calculated: wind direction, windspeeds, and location of maximum windspeed.

Wailes (1986) notes that the method of using these data in problem solving in OMNR operations is "still quite subjective, and possibly to some small extent, intuitive as a consequence of previous experiences".

Other tools now available to the weather technician and the fire boss on site include the radio facsimile recorder with transistor radio, which enables up-to-date weather maps to be received on site. Also available in conjunction with a telephone is a portable computer terminal that permits access to the AES weather computer in Toronto. Automatic weather stations are now standard at most prescribed burn sites many weeks before the burn is planned.

To many this technology is not yet commercially available. Other technology is on the market but the cost is prohibitive. For example, there is a radio/minisonde receiver that will provide additional information on atmospheric pressure, moisture and heights. As well, a computerized balloon theodolite is now available in Canada. Satellite communication is also being tested by OMNR to provide for enhanced communication between the prescribed burn site and the Toronto weather computer.

Computer technology for use in prescribed burning does not end here. With the new decision support system (DSS) now being tested operationally in Ontario, many more planning tools will become available to fire and forest managers. In the near future, fire growth models will be available for determining how best to plan for both ignition and suppression aspects of the burn. A prescribed burn data base is also being developed at the Aviation and Fire Management Centre with the help of staff of the CFS. It is hoped that this data base will encompass at least the past 5 years of historical data compiled from prescribed

[4] Lacharity, L.D. 1986. Minisonde internal correspondence. Ont. Min. Nat. Resour.

burn plans and post-burn reports. It will then form an integral part of all future burn plans so that results achieved on similar sites and under similar weather conditions can be compared. Information on the success of each regeneration treatment used, as well as comparative burn results achieved with different ecosystem classifications, burn intensities, and growth and yield data, are also being incorporated.

The expansion of Ontario's prescribed burn program is a result of many factors. Technology has played a major role, and it is hoped that by combining this technology with the experience and knowledge gained over the years, forest and fire managers in Ontario will be able to ensure that their clients have safe, efficient and effective prescribed burns.

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THE USE OF GENETICALLY IMPROVED SPECIES AND SCIENTIFICALLY PLANNED CROPPING SYSTEMS TO GROW THE FORESTS OF THE FUTURE

R.J. Day, Professor
School of Forestry
Lakehead University
Thunder Bay, Ontario

Abstract.—High growth rates of tropical/southern hemisphere exotic plantations are compared with low growth rates of natural Canadian forests. If Canada is to continue to compete on world markets, crops of genetically improved species must be established now and managed for high yields and economic returns. 'Crop planning', a method for forecasting the development of silviculturally managed forest crops, is defined and explained. Crop plans developed for lodgepole pine and Sitka spruce pulpwood and sawlog production in the United Kingdom are presented and comparable crop plans for jack pine and black spruce are proposed for Ontario's boreal forest. The latter crop plans forecast that yields 10 m^3 ha^{-1} $year^{-1}$ could be achieved in Ontario with proper crop management; with both genetic improvement and improved crop management even higher yields should be obtained.

Résumé.—Le rythme de croissance des plantations exotiques des tropiques et de l'hémisphère sud est comparé à celui, plus faible, des forêts naturelles canadiennes. Pour que le Canada demeure compétitif sur les marchés internationaux, on doit dès maintenant établir des peuplements supérieurs sur le plan génétique et les aménager de manière à assurer un rendement et une rentabilité économique élevés. La planification des peuplements, méthode employée pour la prévision du développement des peuplements forestiers aménagés par traitements sylvicoles, est définie et expliquée. Des plans sylvicoles établis pour la production de bois de pâte et de sciages de pin tordu et d'épinette de Sitka au Royaume-Uni sont présentés, et des plans comparables pour le pin gris et l'épinette noire sont proposés pour la forêt boréale de l'Ontario. Ces derniers prévoient un rendement possible de 10 m^3/ha en Ontario si un aménagement adéquat est assuré; l'utilisation de matériel génétiquement supérieur et l'application de méthodes améliorées d'aménagement devraient permettre d'obtenir des rendements encore plus élevés.

INTRODUCTION

Forestry is entering a new age in which genetically improved forest crops are being grown in scientifically planned cropping systems (Evans 1982, Sedjo 1984). The reason for this change is the ever more pressing need to grow 'industrial' wood in plantations as exploitation reduces the world's accessible natural forests. Many such plantations were established from the tropics to the cool-temperate southern hemisphere in the 1970s and 1980s, and it is timely to assess the potential for growing similar industrial plantations in Canada. With increasing efficiency in transportation systems it appears that the new tropical and southern hemisphere exotic plantations may provide formidable competition for the 'traditional' sources of wood in the industrialized northern hemisphere.

Table 1 gives the growth rates of managed forest and plantations in various parts of the world (Wood 1975, Evans 1982). It shows that the yield of wood in m^3 ha^{-1} $year^{-1}$ ranges from an average of 1.0 for Canada to 60.0 for eucalypt *(Eucalyptus* spp.) plantations in the tropics. Although I contested the Canadian figure when teaching "Tropical Plantation Forestry" to fourth-year forestry students in the Department of Forestry at the University of Technology in Lae, Papua New Guinea, the *very low* yields recorded in Canada make me uneasy. Perhaps we have not tried to produce wood efficiently yet? Perhaps growth in the cool-temperate zone is slower than elsewhere? If the Swedes have 'learned to manage' their forests so well, how is it that they average only 3.3 m^3 ha^{-1} $year^{-1}$?

Table 2 provides additional information on the yield of both pulpwood and integrated pulpwood and sawtimber crops in the world and in particular in Europe and the southern and Pacific northwestern regions of the United States (Sedjo 1984). It again shows that the yield of wood in m^3 ha^{-1} $year^{-1}$ ranges from 5.0 for Norway spruce *(Picea abies* L.) in Scandinavia to a high of 25.0 for eucalypts in central Brazil and Radiata pine *(Pinus radiata* D. Don.) in New Zealand. The information presented in Tables 1 and 2 does not indicate that it will be easy to manage forests and to grow plantations in Canada that can compete with those now growing in the rest of the world. It even suggests that there may be difficulties in growing competitive industrial wood in northern Europe and that the Baltic and Scandinavian countries, our traditional competitors, may suffer equally from competition from the tropics and the southern hemisphere.

To compete with those in the rest of the world, Canadian crops of managed stands and plantations must be regenerated, tended and harvested to replace the old-growth forest that we Canadians have traditionally logged, processed and exported to sustain our economy. Such crops will rarely be the same in species composition, stand structure or rotation length as the old-growth forest stands they replace because they must be:

1) high-yield, economically efficient crops that can produce both valuable products and the highest possible return on the investment made to establish and tend them;

2) crops composed of genetically improved species or cultivars that can be efficiently and economically reproduced, tended and harvested as *managed crops;*

3) crops that can maintain a rate of mean annual increment throughout both their optimum and potential commercial rotations that is >10 m^3 ha^{-1} $year^{-1}$.

The objectives of this paper are to:

1) examine the genetics of the coniferous species currently being regenerated as forest 'crops' in the Boreal and Great Lakes-St. Lawrence forests and to discuss the genetic improvement needed for scientifically designed silvicultural cropping systems;

2) review the 'crop planning method' and the density models on which it is based;

Table 1. World growth rates in managed forest and plantations (after Wood 1975, Evans 1983).

Region	Yield m^3 ha^{-1} yr^{-1}	Rotation (years)
Canada (average)	1.0	-
Siberia	1.4 - 1.4	-
Sweden (average)	3.3	60 - 100
United States (average)	2.6	-
New Zealand (pines)	18.0 - 30.0	20 - 40
South Africa (pines)	10.0 - 25.0	20 - 35
Subtropics (eucalypts)	5.0 - 30.0	8 - 25
Tropics (hardwoods)	25.0 - 35.0	8 - 20
Tropics (pines)	15.0 - 45.0	8 - 30
Tropics (eucalypts)	up to 60.0	7 - 20
Tropics (managed forest)	0.5 - 7.0	-
Tropics (managed Dipterocarp)	up to 17.0	-

Table 2. Worldwide growth rates in representative plantations (after Sedjo 1984).

Region	Pulpwood		Pulp and timber	
	Yield $m^3\ ha^{-1}\ yr^{-1}$	Rotation (yr)	Yield $m^3\ ha^{-1}\ yr$	Rotation $(yr)^{-1}$
Southern United States				
Loblolly pine *(Pinus taeda* L.) (avg site)	11.9	30	12.4	35
Loblolly pine (high site)	17.9	30	17.7	35
Pacific Northwest (U.S.A.)				
Douglas-fir *(Pseudotsuga menziesii)* [Mirb.] Franco) (avg site)	12.8	40	14.4	50
Douglas-fir (high site)	13.6	30	20.0	40
South America				
a) Brazil (Amazonia)				
Caribbean pine *(Pinus caribaea* Morelet)	16.0	12	16.0	16
Gmelina *(Gmelina* L. spp.)	18.0	7-18	18.0	12
b) Brazil (central)				
Eucalypts *(Eucalyptus* L'Herit spp.)	25.0	7-18	25.0	19
c) Brazil (southern)				
Loblolly pine	20.0	12	20.0	20
Chile				
Radiata pine *(Pinus radiata* D. Don.)	25.0	22	22.0	32
Oceania				
Australia				
Radiata pine	21.0	29	17.4	35
New Zealand				
Radiata pine	25.0	18	25.0	27
Africa				
Union of South Africa				
Patula pine *(Pinus patula* Schl. & Cham.)	16.1	15	16.0	26
Gambia-Senegal				
Gmelina spp.	15.0	10	15.0	20-40
Eucalypts	17.0	7	17.0	10-30
Europe				
Scandinavia				
Norway spruce *(Pinus abies* Karst.)	5.0	50	5.0	80
Asia				
Borneo				
Caribbean pine	14.0	15	13.5	20

3) compare and contrast the crop plans developed for lodgepole pine *(Pinus contorta* var. *latifolia* Engelm.) and Sitka spruce *(Picea sitchensis* [Bong.] Carr) in the United Kingdom with proposed crop plans for jack pine *(Pinus banksiana* Lamb.) and black spruce *(Picea mariana* [Mill.] B.S.P.) in Ontario.

GENETIC CHARACTERISTICS OF CONIFEROUS SPECIES NOW USED FOR FOREST CROPS

The genetics of the native coniferous species for future forest crops must also be examined carefully. Even though the volume ha^{-1} of many native tree species appears to be acceptable over the long rotations of old-growth forest, their yields fall far short of the 10 $m^3\ ha^{-1}$ year needed if forest crops in Ontario are to compete with those in the southern hemisphere or tropics. To achieve such yields both genetic improvement of crop species and scientifically planned cropping systems will be needed. Genetically improved species or cultivars must be planted or seeded and spaced at a designated spacing, tended and grown to a minimum merchantable diameter as an economic crop. The scientific planning of the new cropping systems is as urgently needed as genetic improvement. It seems that forest geneticists have been far too preoccupied with increasing the growth rate of forest tree species and have not been breeding for optimum yield in scientifically managed crops. The crop species available at present for new coniferous crops in Ontario are listed and described to illustrate these statements.

Black spruce is an ideal crop species for planting because it is a superb root regenerator and has a fine branch habit that imparts minimal knottiness. Hence, it may be established at optimal initial spacings in plantations and grown to merchantable size without non-commercial thinning. It is not an ideal species for natural reproduction because of its small seed, and need for protection during germination and slow postgerminative growth. Genetic improvement of its growth rate up to 20 years is urgently needed because it develops basal area (BA) and volume ha^{-1} slowly. For example, only 14.4 m^2 of BA and 42 m^3 of volume are developed by age 20 in the better natural stands in Ontario (Site Class 1a [Plonski 1974]). Owing to its tolerance, black spruce in Site Class 1a natural stands does not appear to suffer from check. It develops 45.4 m^3 ha^{-1} of BA and 320 m^3 of volume at age 60, and is therefore one of the more productive species in Ontario.

White spruce (*Picea glauca* [Moench] Voss) is not an ideal crop species for planting because it is a very poor root regenerator and often goes into check after outplanting. In addition, white spruce is very frost-sensitive until its height exceeds 3-4 m. If white spruce is established at optimal spacing it tends to be damaged by frost and is slow growing, heavily branched and knotty. To overcome these difficulties, one must establish and grow white spruce under the protection of a nurse crop (e.g., trembling aspen [*Populus tremuloides* Michx.]) and release it at a height of 3-4 m. It is not an ideal species for natural regeneration because of the infrequency of seed years, low viability and need for protection during germination, and slow post-germinative growth. Genetic improvement of its root regenerating potential and frost hardiness are urgently needed. Although white spruce appears to grow well in the later stages, its propensity for very slow growth up to age 15 reduces its potential as a crop species. Even though there is little information on the growth ha^{-1} of white spruce natural stands in Ontario, Kabzems (1971) shows that it produces up to 42 m^2 of BA and 256 m^3 of merchantable volume ha^{-1} at age 60 in Saskatchewan, a fact that suggests it may be less productive than black spruce in short-rotation crops.

Jack pine is not an ideal crop species for planting because of its inconsistent but often heavy branch habit and poor root stability of both bare-root and container stock between 10 and 15 years of age. The heavy branch habit of jack pine may require regeneration at close spacing and non-commercial thinning. Jack pine natural reproduction after scarification and cone scattering is clumped and poorly distributed so that it must be spaced. Genetic improvement of its branch habit and root form after outplanting is urgently needed if jack pine is to be grown as a crop. Whether or not genetic improvement of its growth rate is needed is not known because most natural stands appear to be in check as a result of severe overstocking and intraspecific competition at an early age. (Site Class 1 has 6401 stems ha^{-1} at age 20.) Hence, although natural Site Class 1 jack pine stands can develop 21.9 m^2 ha^{-1} of BA and 102 m^3 ha^{-1} of volume at age 20, they produce only 27.4 m^2 ha^{-1} of BA and 252 m^3 ha^{-1} at age 60 (70% of that produced by Site Class 1a black spruce). This makes jack pine one of the least productive species in Ontario.

Red pine (*Pinus resinosa* Ait.) is an ideal crop species for planting in the Great Lakes-St. Lawrence and the southerly frost-free Boreal sections of Ontario because it may be planted at wide spacing without risk of developing the severe branch habit or form problems of jack pine. It is not an ideal species for natural reproduction because of the infrequency of seed crops, the difficulties of establishing it from seed and its intolerance of competition. Red pine appears to be an ideal crop species and genetic improvement is hardly needed. Because natural Site Class 1a red pine stands develop 22.3 m^3 ha^{-1} of BA and 109 m^3 of volume at age 20 and 4.4 m^3 ha^{-1} of BA and 391 m^3 of volume at age 60, the species is the second most productive in Ontario. (White pine is slightly better at 60 years.)

White pine (*Pinus strobus* L.) is not an ideal crop species either for planting or for natural regeneration because it is acutely deformed (especially in open plantations) by the white pine weevil and very subject to blister rust attack. After considerable expenditure little genetic improvement has been achieved to combat either of these serious problems. Natural Site Class 1 white pine stands develop 26.2 m^3 ha^{-1} of BA and 74 m^3 of volume at age 20 (more BA and less volume than red pine at the same age) and 41.3 m^3 ha^{-1} of BA and 400 m^3 of volume (slightly more volume than red pine) at age 60. Hence, it is the most productive species in Ontario.

A REVIEW OF THE CROP PLANNING METHOD

To develop a scientifically planned forest cropping system it is essential to develop and compare methods of growing forest tree crops. The crop planning method represents a first attempt to list the critical silvical information needed to grow forest crops, in conjunction with appropriate density models

based on the 3/2 rule (or Reciprocal Yield Law) (Kira et al. 1953, Shinozaki and Kira 1956, Yoda et al. 1963, Drew and Flewelling 1977, Harper 1977), so that forecasts can be made of the approximate yields per hectare of optimally managed crops. As the crop planning method is described fully in Day (1985) it will not be presented in further detail here.

A crop plan may be defined as a clearly thought-out silvicultural plan that includes the following:

1) a pre-cut inspection to assess a) species composition, b) stand structure, c) total volume or BA, d) mean annual increment (MAI) of the stand to be harvested (if any), and e) site quality or yield class for the crop to be grown;

2) a prescription for the species and crop type to be grown in accordance with a crop density model such as Spacing Factor % (SF %) (Wilson 1979; Day 1985, 1986) or Reineke's Stand Density Index (RSDI) (Reineke 1933; Daniel et al. 1979; Vezina 1984a, b; Day 1985, 1986), and an estimate of the maximum volume or BA per hectare that the site can produce;

3) a forecast of the rotation length and the expected merchantable yield of the crop;

4) a prescription for the harvesting method;

5) a prescription for slash disposal and site preparation;

6) a prescription for the reproduction method including the initial spacing of plantations or spacing of natural reproduction;

7) a prescription for weeding the crop;

8) a prescription for tending, by cleaning, pruning or thinning the crop;

9) a forecast of the economic return from the crop.

Crop plans should be prepared for each of the species, site types, and desired crop types to be grown in any productive commercially managed forest.

The use of well designed crop plans will provide information on the type and quality of wood expected from a commercially managed forest.

To develop effective crop plans the silviculturist must know:

1) the critical silvics of the species to be grown in the crop or information on the biological behavior of the species that is needed to grow it as a managed crop. This includes information on the genetic behavior of the species when it is grown as a crop, the most suitable and dependable reproduction methods, the best site preparation methods for establishing and developing the crop, seed viability or stock types to be used, the best sowing and planting methods and most suitable sowing or planting periods for the crop species during the growing season, any problems or difficulties in growing the species as a crop (e.g., root deformation of bare-root and/or container stock causing lack of stability as the crop develops), the need for weed control and release, and other forms of tending such as cleaning or spacing etc.);

2) the desirable initial spacing of each crop species (This may be the density at which the crop species reaches its optimum rotation (OR) (the rotation of maximum productivity) or a desirable commercial rotation (CR) (the rotation of the first commercially feasible harvest). Usually the CR is equal to the OR plus the minimum number of years needed to reach merchantable diameter. For well managed crops the initial density usually should be set at the density of the first commercial harvest, with an allowance for mortality as defined in the critical silvics of the species. For some species it may have to be set higher than the density of the first commercial harvest because of branchiness and the need to 'train' the crop (e.g., as in all tolerant hardwoods and branchy conifers such as jack pine). Where initial spacing is closer than the density of the crop at the first commercial harvest, the crop will have to be thinned non-commercially.);

3) the length of the OR, so that at the OR the crop may be: a) harvested for pulp, b) allowed to overstock to achieve a higher mean diameter before it is harvested for pulp, or c) thinned to remove pulpwood and allowed to grow further to produce sawlogs or veneer;

4) the optimum densities that must be maintained by thinning throughout the rotation to grow crops of sawlogs or veneer

(These can be readily determined in first approximations by selecting a trial stand density index (e.g., SF % (Wilson 1979), RSDI (Reineke 1933) or 3/2 Rule Density Diagram (3/2 RDD) (Drew and Flewelling 1977, 1979; Flewelling 1980, 1981; Flewelling and Drew 1985) for the species to be grown. Then permanent sample plots can be established in the new crops and the initial SF %, RSDI or 3/2 RDD can be adjusted to produce better second approximations as the crop grows and develops.)

By designing well thought-out crop plans for each species and site type selected for the production of forest crops, it is possible to re-evaluate, in terms of rate of growth, the productivity of the forest stands supplying any commercial forestry company.

A Comparison of Well Developed Crop Plans for Lodgepole Pine and Sitka Spruce in the United Kingdom with Proposed Crop Plans for Jack Pine and Black Spruce in Ontario

The crop plans for Yield Class 10 (10 m^3 ha^{-1} $year^{-1}$) lodgepole pine (Table 3, Fig. 1 and 2) and Sitka spruce (See Table 6, Fig. 5 and 6) are derived directly from the Forest Management Tables (metric) developed in the United Kingdom (Hamilton and Christie 1971). Both these crop plans are for typical low-productivity plantations in the United Kingdom that are similar in some respects to plantations in the Boreal forest of Ontario. As the United Kingdom Forest Management Tables were developed from permanent sample plots in thinned plantations measured from 1922 to 1971 (49 years) they provide a unique record of the growth and development of managed forest crops. It is important to note that the crops proposed for jack pine and black spruce would be for pulpwood or small sawlog and pulpwood chip production, and such crops would not be thinned but would be harvested soon after the time of first thinning.

Crop Plans for Lodgepole Pine and Jack Pine

The crop plan for Yield Class 10 lodgepole pine in the United Kingdom shows that this species is thinned so that the SF % range after thinning is from 18.1 to 21.3% and the RSDI range is from 3073 to 2408 (Table 3).

The crop plan developed for jack pine in Canada (Table 4) is set up so that the spacing $factor_{min}$ before thinning = 17.5% and the spacing $factor_{max}$ after thinning = 21.0%. The equivalent ranges for the RSDI are 2508-2842 before thinning and 1743-1977 after thinning. In practice, most Site Class 1 jack pine crops should be harvested for pulpwood between ages 24 and 30 when the mean diameter ranges from 11.2 to 13.9 cm.

Table 3. Crop plan for lodgepole pine Yield Class 10 (60), site index 21 m - plantation in the United Kingdom (Hamilton and Christie 1971).

Date	Age	No.	Silvicultural operation	Top height (m)	No./ha	Site Index (m)	SF%	RSDI	Mean DBH	BA/ha	No. of rings per cm	Min ring width (mm)	Comments
1986		1	evaluation site afforestation										Afforest impeded moorland site.
1987	0	2	site preparation										Drain with Parkinson Ironworks plow.
1988	1	3	plant 4306 2+0 PNco		4306	1.52							Plant on berms of upturned furrows. Amend with basic slag (P_2O_5).
1990	3	4	spray release	1.0		1.52	100						Use 0.5 kg a.i./ha of glyphosate, spray after mid-August.
2007	20	5	thin before		3754	1.63	18.1	483		33.8			1021 trees removed or 6.1 m^2 BA/ha
			after	9.0	2733	1.91	21.3	3073	10.7	24.6	3.73	2.86	
2017	30	6	thin before		2733	1.91	13.7	5526		50.3			1439 trees removed or 15.1 m^2 BA/ha
			after	14.0	1294	2.77	19.9	2617	15.7	25.2	4.00	2.50	
2027	40	7	thin before		1794	2.77	15.4	5458		40.2			471 trees removed or 9.6 m^2 BA/ha
			after	18.0	823	3.48	19.4	2505	20.4	27.0	4.26	2.35	
2037	50	8	thin before		823	3.48	16.5	33.76		37.4			236 trees removed or 7.7 m^2 BA/ha
			after	21.1	587	4.12	19.6	2408	24.7	28.0	4.65	2.13	
2047	60	9	final harvest OR = 60	23.8	587	4.12	17.3	2901	27.7	35.31	6.66	1.50	

	(m^2)	(%)
total BA/ha 1) main crop =	35.31	48
2) thinnings =	38.50	52
	73.81	100

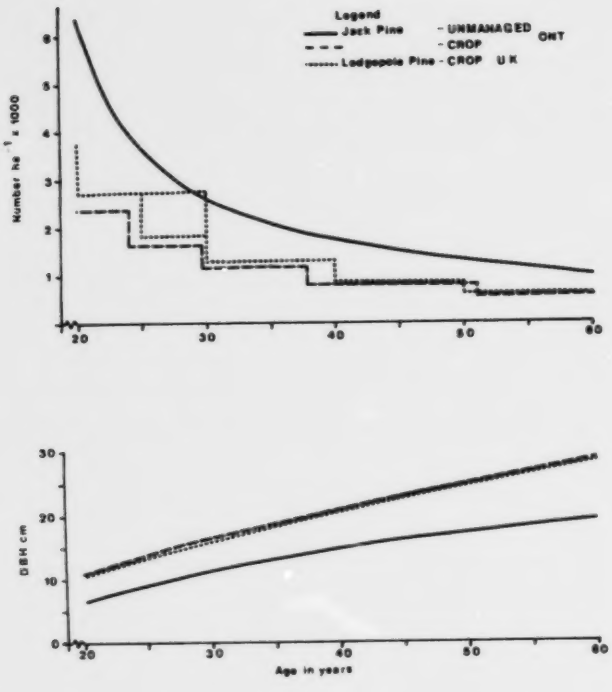

Figure 1. A comparison of numbers/ha/age and DBH/age of unmanaged and managed Site Class 1 jack pine in Ontario with planted and thinned Yield Class 10 lodgepole pine in the United Kingdom.

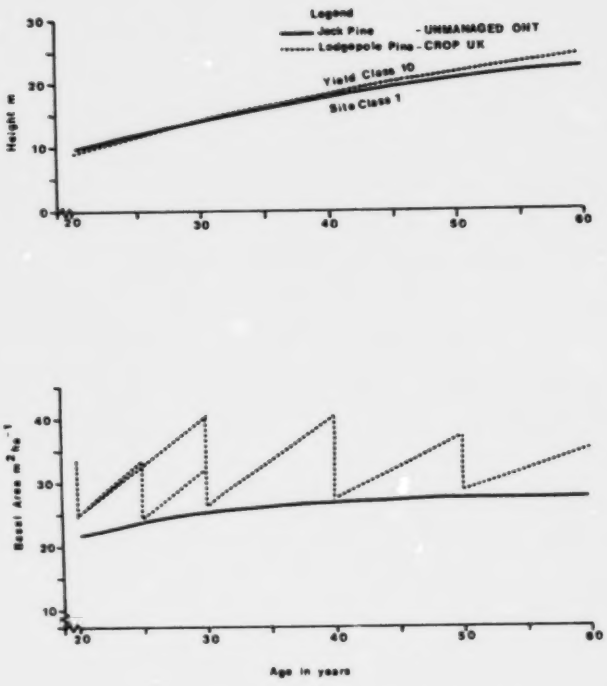

Figure 2. A comparison of height/age and basal area/age of unmanaged and managed Site Class 1 jack pine in Ontario with planted and thinned Yield Class 10 lodgepole pine in the United Kingdom.

Table 4. Crop plan for jack pine Site Class 1, site index 19.9 managed natural stand in check.

Spacing factor max = 21.0%
min = 17.5%

Date	Age	No.	Silvicultural operation	Top height (m)	No./ha	Site Index (m)	SPI	RSDI	Mean DBH	BA/ha	No. of rings per cm	Min ring width (mm)	Comments
	100	1	precut inspection	24.5	644	3.44	16.1		23.1	27.1	8.66	1.16	'natural forest'.
		2	harvest natural stand										
1987	0	3	site preparation		15,000								Use light drags.
1990	3	4	spray release										If needed spray with 0.5 kg a.i./ha of glyphosate after mid-August.
1992	5	5	assess reproduction		10,000								
2007	20	6	thin[a] before N.C. after	9.7	6,985 2,375	1.19 2.05	12.3 21.3	3409 2694	6.34	21.9 7.3	6.31	1.58	noncommercial thinning 4610 trees cut or 14.6 m^2 BA/ha of slash
2011	24	7	thin before after	11.71	2,375 1,652	2.05 2.46	17.5 21.0	2842 1977	11.22	23.5 16.3	3.57	2.81	723 trees removed or 7.2 m^2 BA/ha
2017	30	8	thin before after	14.06	1,652 1,149	2.46 2.95	17.5 21.0	2775 1930	13.94	25.2 17.5	3.35	1.36	503 trees removed or 7.7 m^2 BA/ha
2025	38	9	thin before after	16.85	1,149 797	2.94 3.54	17.5 21.0	2654 1842	17.10	26.4 18.3	6.33	1.58	352 trees removed or 8.1 m^2 BA/ha
2039	52	10	thin before after	20.23	797 534	3.54 4.25	17.5 21.0	2508 1743	20.8(	27.2 18.9	5.35	1.87	243 trees removed or 8.3 m^2 BA/ha
2067	60	11	final harvest OR = 60	21.80	534	4.25	19.5	2669	25.09	27.4	4.71	2.13	

Growth rates are ridiculous.

	(m^2)	(%)
total BA/ha 1) main crop =	27.4	47
2) thinnings =	31.3	53
	58.7	100

[a]noncommercial thinning

Figure 1 shows the number ha^{-1} and DBH over age for unmanaged Site Class 1 jack pine in Ontario, managed Yield Class 10 lodgepole pine in the United Kingdom, and a proposal for a managed Site Class 1 jack pine in Canada based on the crop plan for lodgepole pine in the United Kingdom. This suggests that, by reducing the density of jack pine in natural stands in Canada to the crop densities used for lodgepole pine in the United Kingdom, it would be possible to grow a fully stocked stand of jack pine with a mean diameter of 27.4 cm at 60 years. Figure 2 shows the height and basal area ha^{-1} over age for the stands described above. The superior basal area in the managed lodgepole pine stand in the United Kindgom appears to be related to the fact that natural fire-origin jack pine stands in Canada, which have an average SF % of 13.5 (Plonski 1974), are in check (displaying suboptimal growth because of severe intraspecific competition) and unable to respond to thinning. This fact was confirmed recently at the Stand Tending Workshop organized by the Canadian Forestry Service and The Manitoba Forestry Branch.

Table 4 and Figure 3 illustrate a crop plan for a natural jack pine stand in Ontario that is allowed to become overdense and go into check and then is thinned at 20 years of age. Owing to the lack of response to thinning the productivity of the stand is very low, and the total BA ha^{-1} produced from the main stand and thinnings at 60 years is 58.7 m^2.

In contrast, Table 5 and Figure 4 illustrate a crop plan for managed jack pine natural regeneration that is thinned or spaced noncommercially at 6 years so that check is avoided and productivity is much higher, and the total BA ha^{-1} produced from the main stand and thinnings is 77.7 m^2.

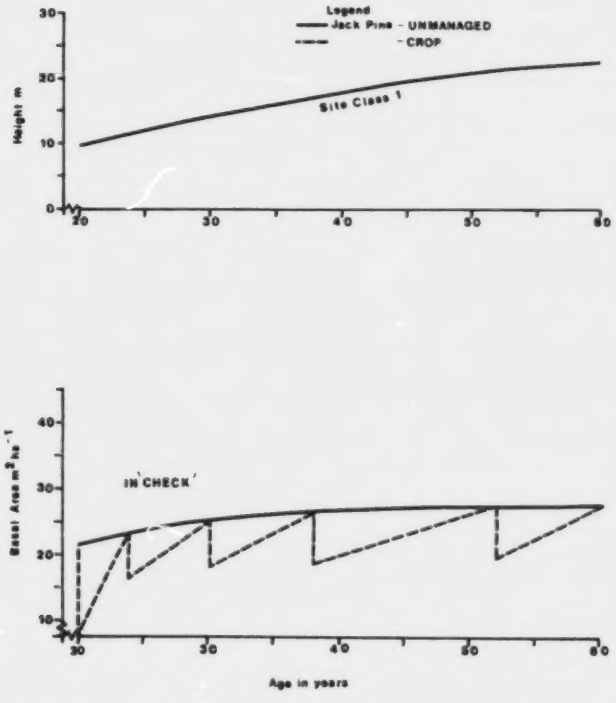

Figure 3. Height/age and basal area/age of natural unmanaged and managed Site Class 1 jack pine in Ontario that remains in check (i.e., the basal area/age curve remains low because of severe early crowding).

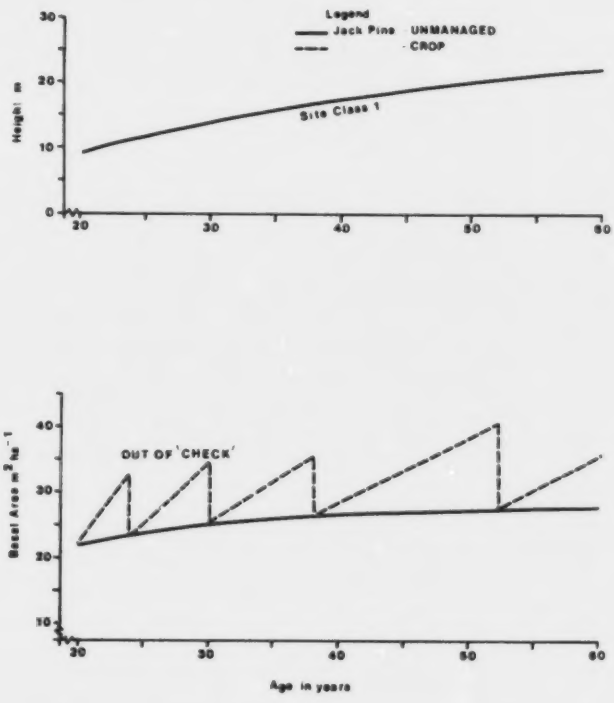

Figure 4. Height/age and basal area/age of natural unmanaged and managed Site Class 1 jack pine in Ontario that does not suffer from check because the stand is spaced to 2500/ha at age 10.

Table 5. Crop plan for jack pine Site Class 1, site index 19.9 managed natural stand out of check.

Spacing factor max = 21.0%
min = 17.5%

Date	Age	No.	Silvicultural operation	Top height (m)	No./ha	Site Index (m)	SPI	RSDI	Mean DBH	BA/ha	No. of rings per cm	Min ring width (mm)	Comments
1986	100	1	precut inspection	24.5	644	3.44	16.1		23.1	27.1	8.66	1.16	'natural forest'
1987	0	2	harvest natural stand										
1988	1	3	site preparation		15,000								Use light drags.
1990	3	4	spray release										If needed spray with 0.5 kg a.i./ha of glyphosate after mid-August.
1992	5	5	assess reproduction		10,000								
2007	20	6	space reproduction	1.0	2,500	2.00	100						Use spacing saws.
2007	20	7	measure crop	9.7	2,375	2.05	21.3	2594	10.84	21.9	3.80	2.65	heavy slash from 4610 stems left on the area
2011	24	8	thin before		2,375	2.05	17.5	3681		32.7			723 trees removed or 10.4 m^2 BA/ha
			after	11.71	1,652	2.46	21.0	2560	13.24	22.7	3.33	3.00	
2017	30	9	thin before		1,652	2.46	17.5	3522		34.2			503 trees removed or 10.4 m^2 BA/ha
			after	14.06	1,149	2.95	21.0	2449	16.24	23.8	4.00	2.50	
2025	38	10	thin before		1,149	2.95	17.5	3348		35.5			352 trees removed or 10.6 m^2 BA/ha
			after	16.85	797	3.54	21.0	2322	19.84	24.6	4.40	2.25	
2039	52	11	thin before		797	3.54	17.5	3424		40.5			243 trees removed or 12.3 m^2 BA/ha
			after	20.23	554	4.25	21.0	2380	25.44	28.2	5.00	2.00	
2047	60	12	harvest crop	21.80	554	4.25	19.5	2801	28.24	34.7	6.28	1.75	(m^2) (%)
													total BA/ha 1) main crop = 34.7 45
													2) thinnings = 43.0 55
													77.7 100

Table 6. Crop plan for Sitka spruce Yield Class 10 (65), site index 18.8 m - plantation in the United Kingdom (Hamilton and Christie 1971)

Date	Age	No.	Silvicultural operation	Top height (m)	No./ha	Site Index (m)	SPI	RSDI	Mean DBH	BA/ha	No. of rings per cm	Min ring width (mm)	Comments
1986		1	evaluate site afforestation										Afforest fresh well drained moorland.
1987	0	2	site preparation										Scarify with TTS Disk Trencher with furrows 1.52 m apart.
1988	1	3	plant 4306 Plai/ha		4306	1.52							Use 2+1 bare-root stock. Plant in early spring at 1.52 x 1.52 m.
1990	3	4	spray release	1.0		1.52	100						If needed spray 1.0 kg a.i./ha of glyphosate after mid-August.
2007	20	5	measure inspection	6.6	3312	1.74	26.4	2761	8.9	20.50	4.49	2.23	not ready for thinning until the BA/ha = 33.0 m^2 at 10 m top height
2017	30	6	thin before		3423	1.74	15.7	4810		41.84			1229 trees removed or 16.45 m^2 BA/ha
			after	11.1	2013	2.23	20.1	2923	12.7	25.4	5.26	1.90	
2027	40	7	thin before		2013	2.23	14.6	4736		52.07			768 trees removed or 11.77 m^2 BA/ha
			after	15.3	1245	2.83	18.5	2929	17.3	29.30	4.35	2.30	
2037	50	8	thin before		1245	2.83	15.1	4202		40.80			386 trees removed or 8.70 m^2 BA/ha
			after	18.8	859	3.41	18.1	2900	21.8	32.1	4.44	2.25	
2052	65	9	final harvest OR = 65	22.5	859	3.41	15.2	3658	25.3	43.03	5.71	1.75	(m^2) (%)
													total BA/ha 1) main crop = 43.03 54
													2) thinnings = 36.20 46
													79.23 100

Crop Plans for Sitka Spruce and Black Spruce

The crop plan for Yield Class 10 Sitka spruce in the United Kingdom shows that this species is thinned so that the SF % range after thinning is from 18.1 to 20.1 and the RSDI range is from 2929 to 2900 (Table 6).

The crop plan developed for black spruce in Canada (Table 7) is set up so that the spacing factor$_{min}$ before thinning is 14.5% and the spacing factor$_{max}$ after thinning is 18.1%. The equivalent ranges for the RSDI are from 4142 to 4252 before thinning and from 2860 to 2733 after thinning. In practice, most Site Class 1a black spruce crops should be harvested for pulpwood between ages 25 and 39 when the mean diameter ranges from 11.4 to 14.3 cm.

Figure 5 shows the number ha^{-1} and DBH over age for unmanaged Site Class 1a black spruce in Ontario, managed Yield Class 10 Sitka spruce in the United Kingdom and a proposal for a managed Site Class 1a black spruce in Canada based on the crop plan for Sitka spruce in the United Kingdom. By reducing the density of black spruce in Canada to the crop densities used for Sitka spruce in the United Kingdom, it may be possible to grow a fully stocked stand of black spruce with a mean diameter of 24.4 cm at 60 years. Figure 6 shows the height and basal area ha^{-1} over age for the stands described above. However, owing to the greater tolerance of black spruce than of jack pine, the basal area of the managed stand differs little from that of the unmanaged natural stand, so that the main advantage of maintaining black spruce at appropriate spacings is to improve growth in DBH and shorten the crop rotation.

Table 7 and Figure 7 illustrate a crop plan for managed black spruce natural regeneration that is thinned or spaced non-commercially at 6 years so that much greater diameter growth can be achieved on a 60-year rotation than is possible in overdense natural black spruce stands.

CONCLUSION

Simple programs of forest management for natural or improved crop species designed to shorten rotations and increase diameter growth and merchantable yield are urgently needed in

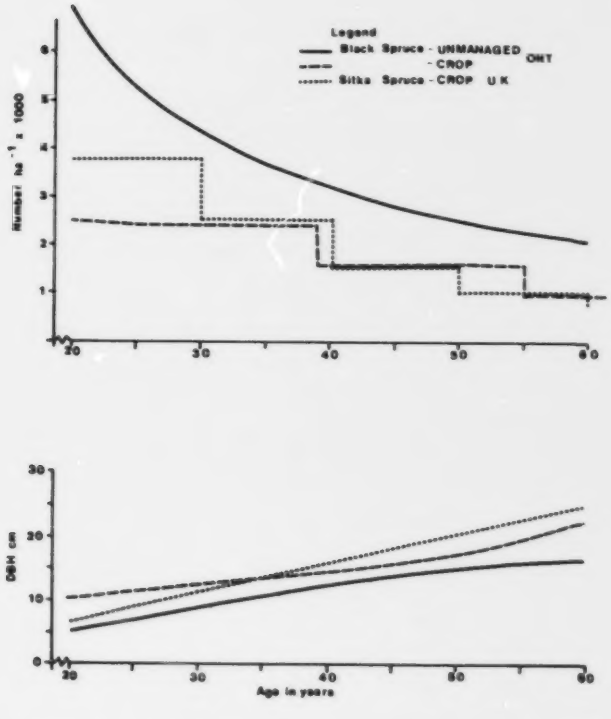

Figure 5. A comparison of numbers/ha/age and DBH/age of unmanaged and managed Site Class 1a black spruce in Ontario with planted and thinned Yield Class 10 Sitka spruce in the United Kingdom.

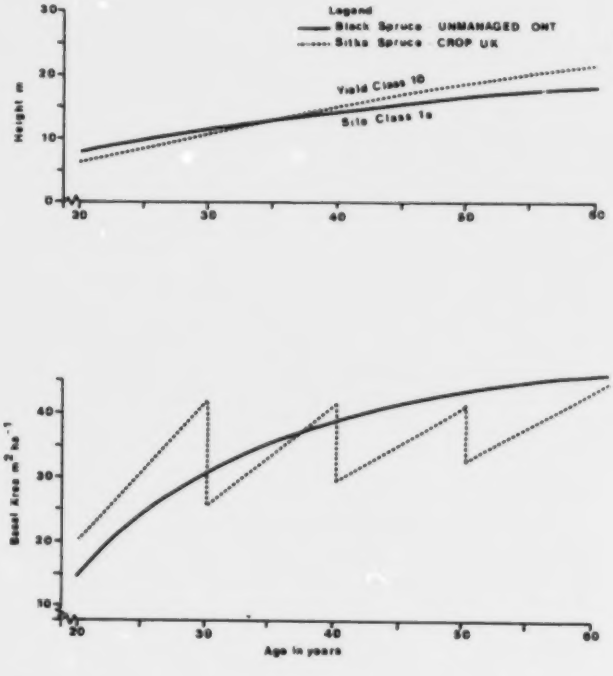

Figure 6. A comparison of height/age and basal area/age of unmanaged and managed Site Class 1a black spruce in Ontario with planted and thinned Yield Class 10 Sitka spruce in the United Kingdom.

Table 7. Crop plan for black spruce Site Class 1a, site index 16 7 m - Managed stand with an optimum rotation of 65 years

Spacing factor max = 18.1%
min = 14.5%
range 3.6%

Date	Age	No.	Silvicultural operation	Top height (m)	No./ha	Site Index (m)	SF%	RSDI	Mean DBH	BA/ha	No. of rings per cm	Min ring width (mm)	Comments
1986	80	1	precut inspection	21.9	1396	2.68	12.2	4402	20.87	47.8	7.67	1.30	slow-growth 'natural forest'
1987	0	2	harvest natural stand										
1988	1	3	site preparation		10,000								Use TTS Disk Trencher
1990	3	4	spray release										If needed spray 1.0 kg a.i./ha of glyphosate after mid-August
1992	5	5	assess reproduction										
1999	12	6	space reproduction		2500								Use spacing saws.
2012	25	7	measure crop	9.7	2375	2.06	21.1	2918	11.40	24.3	4.38	2.28	not ready for thinning; must reach a height of 11.71 m and SF% = 14.5
2026	39	8	thin before		2375	2.05	14.5	4142		38.04			837 trees removed or 13.41 m^2 BA/ha
			after	14.1	1537	2.55	18.1	2680	14.28	24.63	9.75	1.02[a]	
2042	55	9	thin before		1537	2.55	14.5	4252		44.5			549 trees removed or 15.88 m^2 BA/ha
			after	17.6	988	3.18	18.1	2733	19.19	28.62	6.52	1.53	
2052	65	10	final harvest OR = 65	19.4	988	3.18	16.4	3969	24.37	46.1	3.86	2.59	
		11	(may be 65 years)										

	(m^2)	(%)
total BA/ha 1) main crop =	46.1	61
2) thinnings =	29.3	39
	75.4	100

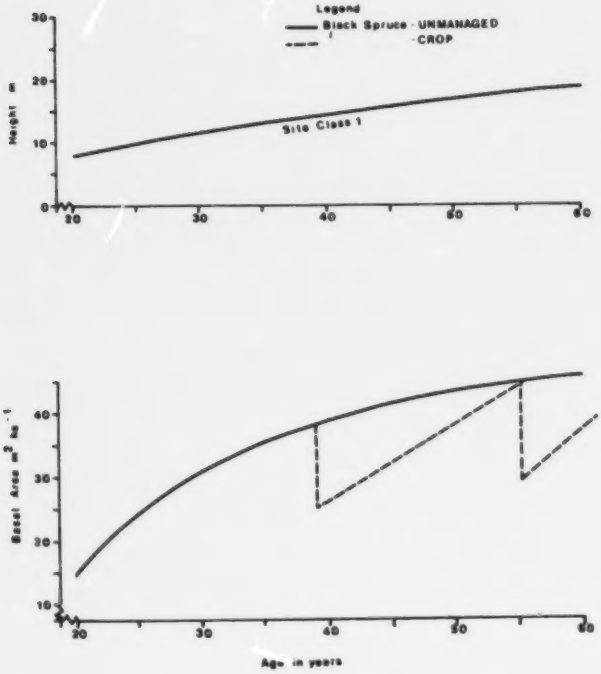

Figure 7. Height/age and area/age of natural unmanaged and managed Site Class 1a black spruce in Ontario that may be in check (i.e., the basal/area curve remains low because of severe early crowding).

Canada's severely exploited forests. The crop planning method is an acceptable way of developing appropriate crop production schedules for future plantation management. The method makes use of well tested density models based on the 3/2 rule and the reciprocal yield law. If the density models used by experienced foresters in Europe and elsewhere are reviewed and adapted to Canadian species and conditions, it should be possible to improve merchantable yields immediately and even the total productivity of intolerant species that suffer from check caused by severe overdensity.

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ACKNOWLEDGMENTS

I wish to thank Dr. T. Eiber for inviting me to address the Canada-Ontario Joint Forestry Research Committee annual meeting; D.A. MacGregor and B. Yuill of the Woodlands Department, Scott Maritimes Ltd., for telling me we need better information on how to grow plantations; K.R. Hamilton and K. Prestridge of the Natural Resources Division, Scott Paper Company (Alabama) for encouraging me to develop a method for preparing crop plans for their company; and all the forestry students who have worked long hours on better and better crop plans that we hope will lead to better silviculture and higher yields in northern Ontario and the rest of Canada.

BIOTECHNOLOGY IN TREE IMPROVEMENT

W.M. Cheliak, Research Scientist
Canadian Forestry Service
Petawawa National Forestry Institute
Chalk River, Ont.

Abstract.—Tree improvement and forest genetics programs in Canada have reached the point at which federal and provincial governments, industry, and universities all have active programs. Despite this level of activity, insignificant amounts of certified, genetically improved seed are available for reforestation programs. Part of the problem is the time lag between the initiation of conventional tree improvement programs and production of commercial quantities of genetically improved seed. A model program, integrating biotechnology and existing programs, is developed to address this time lag problem and offer some solutions.

Résumé.—Au Canada, le gouvernement fédéral, les provinces, l'industrie et les universités ont tous maintenant des programmes portant sur l'amélioration des arbres et la génétique forestière. Malgré cela, on dispose de quantités pratiquement négligeables de graines certifiées de qualité génétique supérieure pour les programmes de reboisement. Le problème est dû en partie à la période de temps qui s'écoule entre la mise en oeuvre des programmes d'amélioration des arbres utilisant des méthodes classiques et la production commerciale de graines génétiquement supérieures. Un programme modèle, combinant la biotechnologie et les programmes existants, est mis au point en vue de résoudre ce problème de temps et d'offrir certaines solutions.

INTRODUCTION

Genetic principles have been applied to breeding and improvement of forest tree crops in Canada for the past six decades. Since then, interest in and commitment to tree improvement programs in Canada have increased considerably, to the point at which most provincial governments have an active tree improvement program within a larger silviculture group. In addition, the federal government has a number of well established research programs in tree improvement across the country. Support is coming from the industrial sector in the form of numerous cooperatives that are being established throughout the country. Finally, and perhaps most significantly, training in forest genetics and tree improvement, at both the undergraduate and the graduate level, is available at the six major forestry schools in Canada. Thus, the research and development activities of a few pioneering individuals have resulted in widespread acceptance and implementation of tree improvement activities in forest management.

Despite the level of activity in tree improvement in Canada, the number of certified, genetically improved trees now entering reforestation programs is insignificant. Of the 10 major species used for reforestation in this country, only one, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), has any stock that originates from seed orchards (Janas 1985). In part, this is a reflection of the long and continued support for the Douglas-fir program by forest industries in British Columbia and the British Columbia Ministry of Forests. In 1982/83 seed from seed orchards amounted to 9.6% of the total seed produced from this species. In spite of the economic importance of species and the long, but sporadic, tradition of spruce improvement in eastern Canada,

no genetically improved stock is available for regeneration programs. The only form of genetic control that has been achieved with species in eastern Canada is the delimiting of seed zones. About 97% of the seeds collected in 1982/83 for reforestation purposes were obtained from wild stands within seed zones for the eastern spruces (Janas 1985). The remaining 3% came from seed collection and seed production areas.

Over all, for the 10 major reforestation species, only 0.2% of the 14.3 billion seeds collected for regeneration purposes has come from seed orchards that will yield genetically improved stock. The situation is expected to improve, but only slightly, in the future. This improvement will come from seed orchards that have been planted, but are not in production at the present time. Generally, there is expected to be a more equitable distribution of species whose regeneration stock originates in seed orchards. Projections and estimates for 1997 indicate that up to 1.6% of the seed used for regeneration will come from seed orchards for the 10 major reforestation species. Clearly, this is not satisfactory. If we are to remain even moderately competitive on the aggressive and rapidly changing world market, we cannot afford to be planting over 98% of the crop with seed collected from wild stands.

One basic problem that has faced all conventional tree improvement programs is the time it takes to produce genetically improved propagules in sufficient quantities for commercial use in reforestation programs. A brief overview of the approach to tree improvement programs will clarify why there is a significant time lag between initiation and delivery.

OVERVIEW OF A CONVENTIONAL TREE IMPROVEMENT PROGRAM

Within a "breeding zone", candidate trees (often called plus trees) are identified and selected from the natural forest. From these candidate trees, scions, and usually open-pollinated seeds, are collected. The scions are used in a grafting program, and are often employed to establish a clonal seed orchard as well as a breeding arboretum. The seeds are used to establish open-pollinated progeny trials. If open-pollinated seeds are not collected, crosses among the selected trees have to be performed to generate seeds for progeny testing. Progeny trials are the basic tool that the forest geneticist uses to evaluate the genetic quality of candidate trees for traits of interest. After sufficient time has elapsed to allow the trees to express any genetically based differences and to stabilize their performance, the seed orchard will be rogued on the basis of progeny trial information. After roguing, progeny originating from random mating of the remaining selected clones in the seed orchard will result in genetically improved stock. Parents for the next generation will be selected from available materials, and usually will be placed in some type of controlled parentage breeding program. Even from the optimistic outline in Figure 1, it is obvious that considerable time will elapse before genetically improved seeds are available from conventional seed orchards.

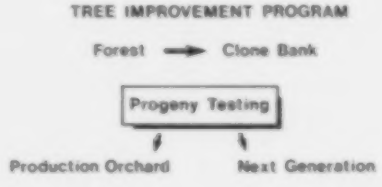

Figure 1. Simplified overview of a conventional tree improvement program. Candidate trees (plus trees) are selected from the forest, and scions are used to make a clone bank. (They are often used for a clonal seed orchard as well). Central to the entire strategy is progeny testing which, in the first generation, is usually done with open-pollinated seeds. As a result of these tests, the seed orchard is rogued and, after random mating among the selected parents, genetically improved seed is produced.

As we have seen, time is a very significant factor in conventional tree improvement programs. The degree to which time affects a program is often related to the biological characteristics of a species. The greater the rotation age and the longer it takes the species to reach sexual maturity, the greater is the delay between initiation of a program and delivery of genetically improved propagules to the field. Unlike many of the programs in the southern United States or in tropical areas, conventional tree improvement programs in Canada require 25 years or more to produce commercial quantities of genetically improved propagules.

At present, research into methods of reducing the time lag between program initiation and delivery of genetically improved propagules to the field programs is being conducted in several areas. Naturally, the more serious the problem, the greater the impact of possible solutions. Consequently, tree improvement programs in the northern hemispheres have the most to gain from innovations that may contribute to reducing the time lag problem in tree improvement. This paper will be limited to a discussion of several biotechnological advances, of ways in which they might be integrated into established, conventional programs, and of their possible contributions to the solution of the time lag problem.

More specifically, it will concentrate on possible applications of micropropagation and somatic embryogenesis as methods of asexual reproduction in forest tree improvement. It will demonstrate how these programs are able to exploit genetic variation more fully at each generation of improvement, maintain more flexibility in the range of possible products, and deliver genetically improved propagules to the field much sooner than a conventional program. Such tree improvement programs will be termed "modern" to differentiate them from conventional programs.

TISSUE CULTURE - ANOTHER OPTION WITH POTENTIAL

The primary advantage of tissue culture is its ability to produce a large number of genetically identical propagules (usually called plantlets or clones) from small pieces of tissue, organs, or individual plant cells. There are two major subdivisions of tissue culture: micropropagation and plant cell culture. Micropropagation typically begins with organized explants (pieces of tissue or organs removed from the donor plant for propagation), such as cotyledons from newly germinated seedlings or buds from trees in the field. Clearly, the desirable starting material would be genetically improved, and would, therefore, come from the breeding program. The primary objective of both micropropagation and somatic embryogenesis (another form of tissue culture) is mass clonal propagation of certified, elite material. The second major subdivision of tissue culture, plant cell culture, typically begins with unorganized explants, such as callus cultures (undifferentiated masses of cells) or single cells (such as protoplasts), which would have come from materials in the breeding program identified as genetically superior. Although the long-term goal of this technology could be mass clonal propagation, its more immediate use is for fundamental research purposes, such as generation and selection of somaclonal variation (genetic variability that occurs as a result of the tissue culture itself), somatic and gametic cell fusion, and genetic engineering.

MODERN TREE IMPROVEMENT PROGRAM - AN OVERVIEW

Geneticists recognize two types of genetic variation: additive and non-additive. Conventional sex-based programs exploit additive variation by increasing the frequency of favorable genes in a population through directional selection and controlled mating among the selected parents. In fact, the only way in which continuous improvement can occur in a population is through the process of sexual reproduction in which additive effects of favorable genes can be increased in frequency.

Non-additive genetic variation results from specific combinations of genes that are brought together either in a single individual or in a family by mating of two specific individuals. The sets of genes in this specific combination interact in such a way that the value for a particular trait is higher or lower than would be expected from additive effects alone. Because exploitation of non-additive effects is dependent on the use of a particular individual or family, it is feasible only by asexual reproduction techniques, in which genes are not allowed to recombine.

For conifers, micropropagation from juvenile tissues is by far the most advanced form of micropropagation. Recently, however, several breakthroughs in this area have unequivocally demonstrated the possibility of using somatic embryogenesis as a means of clonal reproduction. Propagation of conifers from mature tissues remains virtually impossible. This inability to propagate proven, mature individuals clonally would appear to be a significant problem. However, for the majority of forestry purposes, propagation from mature individuals would likely form only a minor component of the overall strategy, again because of time constraints.

In this model program, it will be shown how micropropagation and/or somatic embryogenesis can be integrated into a conventional tree improvement program, and how such a "modern" program can significantly reduce some of the problems associated with time lag.

As with all programs, selections are made from the natural population to establish both breeding and seed production orchards by grafting cuttings onto rootstocks. To maximize potential benefits, a controlled breeding program should be initiated among the selected

trees. This is not really practicable, nor is it necessarily desirable in the first generation. Fortunately, this model can also work with open-pollinated families obtained from each of the selected trees. However, the open-pollinated family option should be considered only for the first generation of improvement. A portion of the seeds from each of these families is used to establish the progeny test, and the remainder is set aside for possible future use. As is usual, the progeny trial is measured at age 5. On the basis of the information obtained, seeds from the best performing families are entered into a juvenile tissue culture program. The clonal reproduction strategy can involve either micropropagation or somatic embryogenesis. This allows for rapid mass clonal propagation of progeny from the best families. Because these plants have not been allowed to grow through to maturity, there will be some concern about the correlation between juvenile performance at age 5 and eventual mature performance. However, this correlation is usually strong enough that it is possible to identify the best- or worst-performing families (Lambeth 1980). This strategy clearly offers a distinct advantage over the only other option at this time, which is continued collection of seed from the wild population. Hence, from a limited amount of material, it is possible to have genetically improved material as early as 5 years after the progeny trials have been established (Fig. 2).

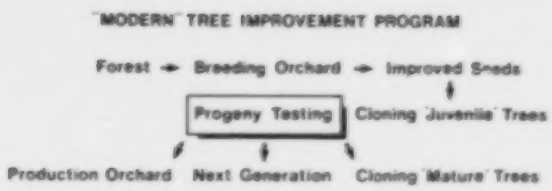

Figure 2. Simplified overview of the proposed modern tree improvement program. Candidates are sampled from the natural population and established in a breeding orchard and a production orchard. Samples of seed are held in a seed bank to await the results of the progeny trial, which may have been established with either open-pollinated or controlled parentage seed. Micropropagation or somatic embryogenesis is used to multiply progeny of the best-performing families. This can begin after the first evaluation, typically at age 5. After the final selection, promising individuals from the progeny trial can be cloned and entered into a clonal evaluation trial, by the strategy of cloning mature trees, to certify their genetic superiority.

Measurement of the progeny trial continues at age 10 and age 15 when the final selection of parents is made for the purposes of roguing the seed orchard. At each of these measurement periods, the set of families showing superior performance is continually refined for the tissue culture and mass propagation portion of the program.

If open-pollinated families are used, only additive effects can be exploited. The level of genetic gain from this strategy will likely be similar, but less than that obtained from the seed orchard program. However, genetically improved trees are established in the forest up to 20 years earlier if the tissue culture strategy is used (Hasnain and Cheliak 1986).

After the final set of parents has been chosen, further genetic gain can be achieved by identifying in the progeny trial individuals that perform significantly above average.These individuals can then be cloned according to the mature tissue culture strategy. However, to ensure that their performance is attributable to genetic superiority, and not simply to environmental effects, tissue cultured plantlets from these elite individuals must be entered into a clonal trial. Consequently, it will be some time before these individuals can be released as certified, genetically improved propagules. Usually, one would like to wait until performance has stabilized at about age 10-15 before making this decision. Therefore, this strategy entails a time lag of approximately 30 years, roughly the same as that for the seed orchard option. For a limited set of elite and specialized material, which is considerably above average in performance, this strategy may be the option of choice. However, for the majority of the propagules, introduction of certified, genetically improved material into the regeneration program as early as possible is most desirable. This strategy becomes all the more attractive if we consider potential genetic gain per unit time. Although we fully expect that genetic gain, in absolute terms, will be less with the early selection and propagation strategy, the gain per unit time and the cumulative genetic gain will be greater.

Although applications of biotechnology in forestry are in the initial stages, the potential of certain of these technologies is clear. Vegetative reproduction by means of micropropagation or somatic embryogenesis, as an additional option to current reforestation

strategies, offers a number of previously unavailable benefits. These include more flexibility in the crop, potentially greater genetic gains and, most important, capture of genetic gain much sooner than is possible from conventional programs. This last benefit directly addresses the time lag problem encountered in Canadian tree improvement programs. Integration of biotechnological opportunities with conventional programs should not pose great problems.

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FOREST MAINTENANCE

CONTROLLING FOREST INSECT PESTS IN CANADA: TOMORROW'S CHALLENGES

B.L. Cadogan, Research Scientist
Insecticide Field Efficacy
Forest Pest Management Institute
Canadian Forestry Service
Sault Ste. Marie, Ontario

Abstract.—Forest insect control must be an integral component of any comprehensive forest management plan. Attempts to control insect pests over large forest expanses were first made in Canada about 60 years ago and since then, three basic methods have been used: 1) 'classical' biological control—the use of natural enemies to induce desirable equilibria between enemy and pest; 2) insecticide control—the application of biological and chemical insecticides to suppress insect population outbreaks; 3) integrated pest management—a combination of methods to obtain optimum benefits. Technological advances and their anticipated effects on insect control in the near future are examined.

Résumé.—Pour être complet, tout plan de gestion des forêts doit comporter un programme de lutte contre les insectes qui s'attaquent aux arbres. Au Canada, les premières tentatives de répression des insectes dans de grandes étendues forestières ont eu lieu il y a environ 60 ans. Depuis lors, trois principales méthodes ont été employées: 1) la méthode "classique" de lutte biologique, qui consiste à utiliser les ennemis naturels des insectes pour établir un équilibre souhaitable entre ces derniers et les ravageurs; 2) l'utilisation d'insecticides, tant biologiques que chimiques, pour enrayer les infestations d'insectes, et 3) la gestion intégrée des ravageurs, qui fait appel à plusieurs méthodes pour obtenir les meilleurs résultats possibles. Le document examine les progrès technologiques réalisés jusqu'à présent ainsi que leurs effets prévus dans un avenir prochain sur la lutte contre les insectes.

INTRODUCTION

The word pest, in its widest application, refers to an unwanted organism, and might encompass insects, diseases, birds, mammals, weeds, brush, etc. I will confine my remarks to insect pests, because it is difficult to generalize all pest situations adequately with a single example and because I'm more comfortable with the subject of insects.

Other colleagues at this symposium are expected to deal with the application technology aspect of pest control; therefore, I shall restrict my presentation to other aspects of the subject.

It has often been stated that forests are Canada's most valuable resource and it is usually assumed that valuable resources should be protected. I had always thought, therefore, that it was well established that Canada's forests must be protected as part of any meaningful management program if they are to continue to provide the basis for a significant part of the economy. Consequently, I am surprised that there is still passionate opposition to forest pest control and that it is still being suggested that there is no need for man's intervention—that, if left alone, forests will be as green as when the Vikings arrived on our shores.

These suggestions, naive and invalid as they are, nevertheless reinforce my opinion that we need to be more convincing in conveying the true situation and importance of forestry. We need to emphasize that the species composition of the primeval forests was significantly different from that of today's forests, that the climax species of the primeval forests in eastern Canada were not plagued by serious pests like the spruce budworm (*Choristoneura fumiferana* [Clem.]) (Carrow and MacFarlane 1985), and that demands on the primeval forests were considerably fewer than they are on today's forests.

If left alone, insect pests, their natural controlling agents and the forests would undoubtedly reach equilibria. (I have used the plural because the balances are never static and population epidemics and collapses would still occur cyclically.) It is also unlikely that levels of the pest population at any equilibrium would be low enough to avoid significant loss of forest productivity.

If we use the Cape Breton highlands as an example of a forest left to itself, we can conclude that a valuable forest resource cannot be left unprotected. We simply cannot risk the loss of forests or reduced forest productivity as a result of non-intervention and we most definitely cannot afford losses at a time when the demand for wood is increasing while the supply seems to be decreasing.

Figure 1 shows trends in world consumption of industrial wood (Leslie 1980) and it indicates, as can be expected, increased demand for wood products since 1960. Unfortunately, it is not as simple to create an accurate inventory and forecast of the wood supply up to the year 2000. With softwoods representing about 70% of the world's consumption of industrial wood, Leslie (1980) used softwood supply as a guideline for total wood supply and postulated that at best there is not a lot to spare. It is evident that, prior to 1930, we might not have been adversely affected by a Cape Breton-like disaster but this is not the case in the 1980s, nor in the foreseeable future. Every reasonable effort to protect or manage our forests must be encouraged and pest control is merely one effort. The question, therefore, is not whether we should control but rather, how best should it be done.

OPTIONS

I think we all agree that not attempting to control forest pests is too risky to be considered an acceptable option, as in most cases it is catastrophic.

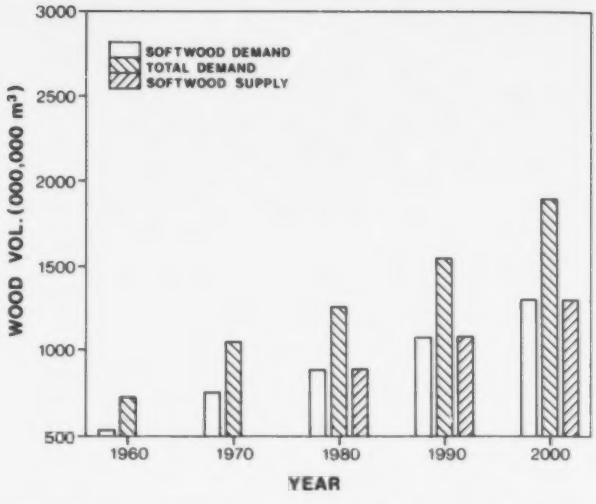

Figure 1. Consumption of industrial wood (Adapted from Leslie 1980).

This leaves three broadly defined methods available to the forest manager for controlling insect pests in forests.

Classical Biological Control

Classical biological control is basically a natural control method that is manipulated by man. The objective of a biocontrol program is to manage and/or introduce natural enemies (parasites and predators) to create and maintain an epizootic. This epizootic is expected to some degree to be a permanent fixture, needing only occasional fine tuning to ensure *acceptable* population equilibria between pest and the augmented enemy complex. If the program is to be successful, the pest population levels at any given equilibria will have to be low enough that the insect damage to the forest will be below the economic injury level. Today, as far as I know, there are very few serious classical biocontrol programs in Canada aimed at controlling important forest insects.

Historically, many classical biocontrol programs have been attempted in Canada (McGugan and Coppel 1962, Anon. 1970, Kelleher and Hulme 1984, Embree and Pendrell 1986). However, except in a few cases, classical biocontrol by means of the inundation of natural enemies has not been very successful in Canadian forests.

I suspect that many of us will propose a variety of reasons for this paucity of success, and I would suggest that the real reasons might be very complex. At first glance, forests appear to be the ideal setting for successful biocontrol. There is botanical contiguity, which seems ideal for the dissem-

ination of beneficial organisms, and the crop is a stable perennial. However, recognition of this contiguity must not lead to a belief that forests are ecologically continuous, for they are not, and it would seem that ecological requirements are the most important determinants of the success or failure of biocontrol programs. A natural forest is a complex of numerous indiscrete ecological "islands". Hence, it is not simple to find one enemy complex that will operate optimally against one pest in all the ecological zones.

Biocontrol, however, is the most desirable (even if it is not the most successful) method of controlling forest insect pests, if we accept Embree and Pendrell's (1986) definition that classical biocontrol by its very nature implies self perpetuation of the enemy complex. By this definition, many of the so-called biocontrol efforts, e.g., the use of *Bacillus thuringiensis (B.t.)*, aren't biological programs at all. Viral and fungal applications could, however, be classified as classical biocontrol.

The clamor for biocontrol apparently is not a new phenomenon. As Embree and Pendrell (1986) remind us, Harry Swetman noted in 1936 that "the widespread interest among laymen and trained entomologists in the biological method is so great that one might be led to believe that it is the most important weapon of the entomologists. This is far from true for undoubtedly insecticides *[not biocontrol]* furnish today *[in 1936]* the major method of controlling insect pests". (italics mine)

Insecticides

The application of insecticides is still the most effective and probably the most efficient method of controlling forest insect pests. The main attributes of insecticides are two: 1) they suppress insect outbreaks and reduce insect numbers to low levels and they usually do it very quickly, thereby ensuring that little damage is done to the host tree; 2) they can be used in relatively small quantities per unit area of forest, thereby offering significant logistical and economic benefits. However, most chemical insecticides are non-selective and there is a high potential for these products, *if used incorrectly*, to have an adverse impact on the non-target environment.

Large forest expanses infested with insect pests can be treated adequately only with aircraft. This has been done successfully since 1927 when calcium arsenate was applied to Nova Scotia forests (Randall 1972).

In 1950, with the advent of DDT and the availability of surplus aircraft, the first concerted attempts to stem the tide of depredation of our forest resources by insects were made by directing aerial control methods against the eastern spruce budworm. Since the 1950s, the chlorinated hydrocarbons have largely been withdrawn from use, and the organophosphates (OPs) and carbamates have been used, the former more extensively than the latter. In the last two years (1985 and 1986), by political decree, the biological insecticide *B.t.* has become the most widely used insecticide in Canadian forests.

In 1965 there were no fewer than 24 insecticides available to the forest manager for use in controlling forest pests. In 1986 there are six chemical insecticides plus *B.t.* (under five trade names) and two viral insecticides registered for aerial use in forestry in Canada. This reduction in the arsenal of products available to the forest manager must be viewed with concern. If the industry is to retain effective control options as the cost of developing new pesticides becomes prohibitive (Kinoshita 1985), emphasis will need to shift, at least temporarily, to developing better formulations and using the existing ones more efficiently. We must constantly be aware that a wide selection of different classes of insecticides minimizes the chances of exerting selection pressure on a pest population. It is therefore imperative that we continue searching for new, effective products to control forest pests.

Integrated Control

The forest manager's final option is integrated control, now called integrated pest management (IPM). IPM is simply an intelligent approach to controlling pests by using the many available disciplines and methods in an integrated way. It used to be thought that IPM, in view of the fact, perhaps, that forests are vastly different from agricultural ecosystems, was based primarily on population dynamics and forest ecology (Stark 1975). A closer examination of this approach, however, will show that it has a much wider base. It advocates managing and encouraging the beneficial components of the system, and recognizes that pesticides will be used; but most important is the fact that it advocates elimination of the ad hoc approach to pesticide use. In reality, all control methods are to some extent integrated approaches. Nevertheless, over the last 20 years there have been remarkable advances in the concept and design of intensive IPM systems for some major forest insect pests (Waters 1986). Research programs on gypsy moth *(Lymantria dispar* L.), Douglas-fir tussock moth *(Orgyia pseudotsugata* [McDunnough]), spruce budworms *(Choristoneura fumiferana* and *C. occidentalis)* and the pine beetles *(Dendroctonus* spp.) have shown us that integrated control (with all that it implies) requires much more than the treadmill approach of spray and evaluate, monitor and spray.

TECHNOLOGICAL ADVANCES AND PEST CONTROL

There is no denying the fact that we are living in an age in which very rapid advances are being made in technology. Consequently, we have a choice. As McLean (1986) suggests, "We as a technological society can draw ourselves up in good order and take the long bow of technology or we can follow vainglorious impulse and narrow ideas of self interest....-and lose."

Advances in biotechnology, primarily molecular biology and genetic engineering, offer exciting prospects for dramatically improving all aspects of pest control.

For those interested in classical biocontrol, preliminary research indicates that new strains of insect predators and parasites that will enhance their *effectiveness* as beneficial organisms can be produced by genetic engineering. These and other findings offer distinct possibilities of extending classical biocontrol as a workable control strategy in Canadian forests. Baculoviruses are also the subject of worldwide research interest. It is now feasible to create more virulent strains of entomophagous fungi and viruses, all with greater potential for self perpetuation in the field. Genetic engineering has facilitated the incorporation of genes that code for toxic products in so-called innocuous organisms, e.g., commonly occurring viruses, thereby making them extremely effective organisms against some insect pests.

To be effective, pest control will always require effective products, whether they be the new strains of organisms for long-term biocontrol or chemical entities for short-term insecticide applications.

We are on the cutting edge of unravelling the mysteries of some of the biological products that might be of tremendous significance. Pesticides such as *B.t.* are being used as a fulcrum for gaining further insight into the possibilities of biotechnology. Genetic manipulation and molecular biology offer exciting possibilities for developing a new class of insecticides. These new products should, by current indications, retain the advantages of traditional control agents while having few of their liabilities.

B.t. produces a glycoprotein toxin, coded by a single gene that has been isolated in plasma DNA (Gonzalez et al. 1982). We have already reached the point at which commercial producers are using other commonly occurring organisms to produce the *B.t.* endotoxin: for example, the *B.t.* gene has been transferred into *Pseudomonas fluorescens* which occurs naturally on the roots of corn (*Zea mays* L.) plants. Insect pests feeding on infected corn roots ingest the toxin and are killed. An American company (Ecogen) has produced a genetically altered strain of *B.t.* that is more potent than the currently available commercial strain by replacing "less active" with "more active" toxin genes (Anon. 1986).

Another area in which there is intense interest is that of insect neuropeptides (called "the brains's little messengers"). Produced in trace quantities, neuropeptides appear to govern all aspects of insect physiology and behavior. It is now possible and quite feasible to place the gene(s) responsible for an insect neuropeptide in another commonly occurring organism. This renders that organism literally a mass production center, thereby making a scarce commodity easily accessible. At present about 15 neuropeptides have been characterized; however, only when further studies unlock their precise neurophysiological pathways will their full potential as pesticides be acknowledged.

Researchers are becoming more convinced that, besides allowing the creation of better products and superorganisms, understanding plant-insect (both pests and beneficial insects) abiotic interactions could be of paramount importance in pest control and that more effort should be devoted to manipulating the plant to combat the pest. Although most efforts to date to use biotechnology in the field of plant sciences have been aimed at organogenesis (promotion of shoot formation), or at somatic embryogenesis in conifers (the latter offers the potential of large numbers of embryos), there are new approaches that involve moving microbial and viral genes directly into plant cells. This, I am sure, will lead to the incorporation of increased insect resistance in the biome of tree species.

Although the influence of technological advances on application technology related to pest control is dealt with elsewhere in these Proceedings, I would like to point out that advances in engineering and electronics will significantly affect formulations, delivery systems, computers, satellites, lasers, etc., and that these improvements will undoubtedly have more positive effects on IPM.

CHALLENGES

The substantial benefits offered by technological changes will not be realized without challenges. Numerous studies have documented what is wrong with forestry. Blame for its ills has been laid appropriately and recom-

mendations have been made so that the house might be set in order.

Cooperative Effort

If the forestry community is to keep abreast of technological developments, all sectors and all disciplines within sectors of that community must work cooperatively. For a long time we have paid only lip service to the idea of cooperation, yet whenever cooperation is needed, each component of the forestry community goes its separate way. This must change. Those involved in pest control, silviculture, economics, and so on, need each other to optimize their efforts.

Research Focus

The second major challenge is to effect a significant change in research focus. Our attitude towards basic research must change. This is not to suggest that applied or mission-oriented research be abandoned; however, we need to recognize that if forestry, and in particular forest protection, is to capitalize on technological advances, all of us who are involved in the discipline must participate in research in these areas. We cannot hope to benefit adequately from incidental "spinoffs" from research done in other disciplines. We must initiate and conduct research aimed at our specific needs. We can no longer afford to view basic research as an unaffordable luxury. On the contrary, basic research is the foundation on which solutions to practical problems are formulated.

Judging from the presentations that preceded this one, I would say we are all convinced that any dramatic breakthrough in pest control will most likely be in the area of biotechnology; indeed, many of our sister disciplines in agriculture are already using molecular genetics as tools aimed at controlling plant diseases, etc.

Our forestry schools and research institutions, private and public, must be provided with the opportunities and incentives to embark on ambitious and innovative research projects, instead of the research that has traditionally focussed more and more narrowly on solving local problems while neglecting the basic research on which all society will ultimately depend. And Canadian society has traditionally been highly dependent on forestry.

The Politics of Uncertainty

If engineering new organisms and biological products can be termed a great achievement, I suggest to you that using these 'tools of the future' will present a monumental challenge.

One of the most serious constraints facing pest control, and particularly forest pest control, at this time is *the politics of uncertainty*. The rules, guidelines and directives governing pest control strategies are changing so often that there is a climate of pessimism in the industry, a climate that threatens to stifle advances. Politicians and bureaucrats are making the technical decisions that the technocrats and forest managers should be making concerning pest control. It would seem to me that, with technology offering distinct benefits, forest managers must assume responsibility for decision making so as to optimize the pest control strategies at their disposal.

Unfortunately, the evidence to date suggests that 'political management' and its uncertainties will increase rather than decrease. This phenomenon is not restricted to Ontario or even to Canada.

There is little doubt that as bioengineered pest control products and organisms emerge in increasing numbers, the moral, ethical and legal issues will loom larger. All of those concerned with forestry and forest pest control (researchers, managers, politicians, bureaucrats and technocrats) will have to define jurisdictions and resolve differences between parties--differences that obviously threaten the management of our forests. The parties will need to coordinate and perhaps regulate biotechnological matters, identify deficiencies and develop standards.

Already in the United States some regulatory agencies (The Environmental Protection Agency and the Food and Drug Administration) have served notice that they intend to tighten regulations concerning bioengineered products that contain genetic material from pathogens, unless that material comes from a well characterized non-coding regulatory region. The Environmental Protection Agency has stated that all new (i.e., intergeneric) organisms will be subject to agency review before they can be released into the environment. This means that even small-scale or research and development testing must be reviewed by the agency. This is a radical departure from the current regulations with respect to chemical and non-biotechnical pesticides.

Even without an official policy, communities are beginning to question the morality and/or legality of "new" organisms as much as, if not more than, they questioned existing pest control practices (Edlin 1986, Klausner 1986, Wilker and Shulman 1986), and perhaps this is an indication of things to come.

In Canada we have yet to arrive at a national policy for guiding the deliberate release of genetically engineered organisms into the environment (Miller 1986). I suspect it will have to be a national policy, inasmuch as some of these organisms could be quite mobile and a provincial policy would be less than effective. I also suspect that we will have a policy similar to that of the United States for the very same reasons.

Despite the technological developments and potential, there is still a veil of uncertainty that must be removed before the accrued benefits are available.

Patience

There is a tendency in today's fast-paced world to expect results immediately, but we must be patient and realistic in our expectations. The advances to which I referred above are far from being definitive, and research with entomophagous material, e.g., biological control, takes time to reach fruition. Colleagues who made their presentations earlier in the symposium have shown that it will be some time before the mass benefits of biotechnology reach us.

We should recognize that before genetically altered organisms or products of genetic engineering can be used widely in forest pest control the public's concerns must be satisfied (Klausner 1986).

Most of the predictions I have made with respect to the benefits of biotechnology are based on the premise that the candidate organisms are passive and that over time they will not resist our manipulating them to our benefit. Experience has shown that advantages created by a single gene are often countered by the pest.

It has been said that the next 10 years will shape the future; since forestry is a significant part of Canada's future, forestry must take a very positive and responsible role in nurturing that shape.

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PESTICIDE APPLICATION TECHNIQUES IN ONTARIO: STATE OF THE ART

S.A. Nicholson
Provincial Application Specialist
Pest Control Section
Ontario Ministry of Natural Resources
Maple, Ontario

Abstract.—In the last decade, the Ontario Ministry of Natural Resources has made significant improvements in ground pesticide application technology, pesticide handling practices, and aerial application technology. Problem analysis has led to simple, cost-effective and environmentally acceptable solutions in many areas. However, some major stumbling blocks remain, especially in aerial application technology.

Résumé.—Au cours de la dernière décennie, le ministère des Richesses naturelles de l'Ontario a amélioré de façon notable les techniques d'épandage de pesticides au sol, les méthodes de manutention des pesticides et les techniques d'épandage aérien. L'analyse des problèmes a permis de trouver des solutions simples, rentables et acceptables pour l'environnement dans de nombreux domaines. Toutefois, il reste encore des problèmes importants, surtout dans le domaine des épandages aériens.

In keeping with the theme of this symposium I will elaborate on the steps taken by the Ontario Ministry of Natural Resources (OMNR) to embrace and incorporate, where appropriate, new technology and techniques in forest management, especially in its aerial spraying programs.

While all of that which is presented here is not "high technology" in the current sense, these "high and low tech" changes represent significant improvements in the manner in which OMNR conducts its spraying programs.

The concepts discussed today address the three areas in pesticide use that have experienced the most dramatic improvements in the last decade:

1. recent developments in ground pesticide application technology
2. technical and procedural developments in pesticide handling practices
3. current trends in aerial application technology.

To complement our progress to date I will highlight the goals we expect to achieve in the near future as well as those that remain elusively distant.

As a discipline, pesticide application is still in its infancy, still as much an art as a science. However, there are many areas in which problem analysis has led to simple, cost-effective solutions.

With respect to recent developments in ground spraying, OMNR has developed several evolutionary (and revolutionary) pieces of equipment, all towed by a skidder. Because it is essential in some parts of the province that we regenerate forested areas without the use of aircraft, several districts have built a variety of ground sprayers designed for use in cutovers for either site preparation or conifer release. This initial concept has been developed to incorporate a variety of "off-the-shelf" equipment and an abundance of "on-the-job" experience. Some of the features incorporated into our recently developed sprayers are as follows:

1. stainless steel spray tanks - no corrosion

2. rollover-resistant design - wide stance, leak-proof tanks

3. Brücke-style hitch - operator safety, ease of operation

4. dependable pumping equipment - Honda equipment with larger fuel tanks

5. electronic flow monitor/control - cab-mounted console

6. radar speed indicator - to ensure that application rate is proportional to ground speed.

Although the radar unit has proven unworkable, the necessity for accurate ground speed indicators and controls can and will be addressed through other "low technology" means, i.e., ground-driven mechanisms.

The second area I wish to highlight is OMNR's improved pesticide handling procedures.

While certain legislation has enforced these changes in the last decade, it is a better understanding of the potential impact of the pesticides being used, coupled with a heightened respect for occupational hazards, that has led OMNR to invest significant sums in improving our pesticide handling equipment and our operational procedures. We have discovered that there is no substitute for proper training and proper equipment.

Various issues and concerns have led OMNR to review our procedures and our existing capabilities. The most important of these are as follows:

1. current federal and provincial legislation

2. workers' exposure/safety

3. workers' right to know

4. pesticide toxicity

5. environmental contamination

6. general hygiene.

With respect to training, all field staff involved in our pesticide application programs are trained and licensed by the Ontario Ministry of the Environment. We offer additional specialized training and annual updates to nursery staff, aerial navigators, project supervisors, etc., to ensure that all OMNR staff have the benefit of up-to-date information and techniques.

As for technical improvements in our pesticide handling procedures, OMNR has spent nearly $2 million since 1985 on capital equipment, most of which is devoted to pesticide programs. For example, one inexpensive device that is now fitted to all our pesticide storage/mixing tanks and all contracted spraycraft is a Buck Eye 'Dry-Break' coupler (Emco Wheaton). In 1986 alone, the use of these devices saved OMNR an estimated $7,000 worth of *Bacillus thuringiensis* by providing leak-proof couplings for every aircraft load of insecticide. In addition, the use of these devices assured cleaner work sites for field staff--an important consideration, as these work sites are subject to scrutiny by members of the news media and provincial enforcement agencies.

Finally, with respect to my third point of discussion--aerial application technique--it is estimated that OMNR saved over $2.5 million in 1985 alone through the use of newer technology and improved practices.

Aerial application is not new to OMNR; in fact, we have been applying herbicides in this manner for over 30 years, and 1986 marks the 40th anniversary of our provincial foresters' involvement in aerial spraying for spruce budworm control.

It is our belief that the aerial application of pesticides, as sprayable liquid, will continue for many years, and therefore, OMNR must be prepared to conduct these programs in a manner that is both environmentally acceptable and cost-effective.

In an effort to achieve these goals, we have endorsed the use of several types of equipment that will ensure real savings in all of our spraying programs.

The use of on-board flow monitors (Crophawk®) on all spraycraft employed in the 1986 program saved OMNR in excess of $100,000 (estimated) through reductions in aircraft flight time and subsequent fuel and insecticide reductions in our calibration exercises alone. These monitors also allow pilots to check and correct application errors in flight, thereby providing further cost savings.

These are dramatic economies, but bear in mind that the 1986 program covered approximately 750,000 ha and over 100 spraycraft participated in the program.

In the past, and in some other jurisdictions, most of the spraying was conducted with conventional boom and nozzle delivery systems. All insecticide spraying conducted by

OMNR requires the use of rotary atomizers only. The advantages of rotary atomizers are numerous but the most significant is that more economical, efficient atomization is obtained and, as a result, lower volumes are applied while satisfactory levels of protection are maintained. The use of Micronairs® for the 1986 gypsy moth program resulted in a saving of nearly $2.5 million in direct application costs alone.

Conventional wisdom in the United States, where annual gypsy moth spraying programs are conducted by numerous organizations and jurisdictions in the Northeast, has it that high-volume (i.e., 10 L/ha) boom and nozzle applications provide the best results. Using epxerience gained through Canadian forest protection programs, OMNR decided that the volume of pesticide to be applied could be reduced from 10 to 6 L per ha. Applied with rotary atomizers, this lower volume would, it was believed, produce satisfactory results and ensure foliage protection through increased efficiency of atomization, canopy penetration and foliar deposition. In addition, a larger area could be treated within the same length of time, or conversely, the same-size program could be conducted with fewer aircraft. There were other significant but unassessible savings through the reduction in air fleet, airports, capital equipment and personnel requirements, all as a result of using these atomizers.

In 1978, aware of the theoretical superiority of the atomizers, OMNR embarked on a program designed to incorporate these technological improvements into our herbicide spraying programs. By using rotary atomizers we hoped to realize significant cost reductions and improve our level of vegetation control.

But technology isn't everything. In fact, we found a technological gap in that no agency could accurately quantify the droplet spectra produced and the results obtained in our project. In the last six years, we have dealt with the National Research Council, the Forest Pest Management Institute, and the Ontario Research Foundation, all of which have provided limited levels of successful analysis for us.

So we have come to an impasse. There are other methods of quantifying the droplet spectra produced. The next step is field testing to assess the relative efficiency of any of the application techniques to determine if the transition from theory to operational improvement will result in our achieving the goals we have set.

As described above, there are three areas in which OMNR has incorporated cost-effective, readily available, and appropriate technology: ground spraying, pesticide handling, and aerial application.

There are still some major technological stumbling blocks, especially in aerial application. Spraycraft navigation and accurate localized weather predictions remain elusive concepts that must be addressed by agencies other than OMNR. In addition, some investigational work into the appropriate use of spray additives should be considered.

OMNR's strength still lies outside the realm of technical research--it is in the dedication and commitment of its staff to participation in and completion of the projects, regardless of the legislative or technological challenges that must be met.

IMPLICATIONS FOR PROFITABLE THINNING: UTILIZATION OF A MINI FORWARDER AND SMALL SKIDDER

H.A. Bax, R.P.F., Manager

and

L. Van Damme, R.P.F., Project Forester
KBM Forestry Consultants Inc.
Thunder Bay, Ontario

Abstract.--A Swedish mini forwarder consistently outproduced a small skidder in three winter thinning operations. Production levels of 3 m^3/man day were achieved. Highly skilled and motivated workers, as well as large wood (20 cm DBH+) averaging four pieces per stem and growing on level terrain with good access to truck roads, would be necessary to realise a profit.

Résumé.--Au cours de trois coupes d'éclaircie hivernales, le rendement d'un mini-porteur suédois a constamment dépassé celui d'un petit tracteur de débusquage. La production a atteint 3 m^3 par journée-personne. Pour réaliser un profit, une équipe très spécialisée et très motivée aurait besoin de trouver, sur un terrain plat donnant facilement accès à des routes pour camions forestiers, du bois de fortes dimensions (au moins 20 cm de diamètre à hauteur de poitrine) procurant en moyenne quatres pièces par tige.

INTRODUCTION

Thinning refers to cutting in immature stands to stimulate the growth of residual trees (Smith 1962). Economic analyses usually show that post-establishment treatments can be worthwhile because of the relatively short period that elapses before a return on investment is realized, and the potential for more value-added products from the residual trees harvested in the final cut (Fraser 1985).

In northwestern Ontario, many contracts have recently been tendered for precommercial thinning or "juvenile spacing" of dense, small-stemmed jack pine (*Pinus banksiana* Lamb.) in the 10- to 30-year age classes. Material cut in these thinnings is normally left on the ground.

Thinnings in older plantations (25 yr+) or natural stands can produce material large enough for conventional roundwood production, for which a market already exists. Norkooli and Towill (1986) suggest that 5,000 ha of plantations are candidates for commercial thinnings in the North Central Region of Ontario and indicate that as many as 15,000 ha could become available in 5 years.

In 1985, KBM Forestry Consultants Inc. received funding through the Canada-Ontario Forest Resource Development Agreement (COFRDA) to develop and field test economically attractive thinning systems under a variety of site conditions. A secondary objective was to explore winter thinning operations as a method of stabilizing the currently seasonal silvicultural work force. For this reason, only low-capital, labor-intensive systems were considered.

In early 1986, KBM purchased a JH127 Swed Caddy mini forwarder with a rated capacity of 1 m^3/load, manufactured by Granges Metallverken in Arjang, Sweden. A ski-equipped trailer was also employed. This paper describes our thinning experiences with the Swed Caddy and a small conventional Timberjack Model 230 skidder. Conditions in which these labor-intensive thinning systems might be profitable are identified.

Conditions contributing to productivity include forwarding distance, piece size, ground and snow conditions, work planning, tree marking, thinning method, load size, harvesting system, stand conditions, training, payment method, utilization standards, etc. Only some of these conditions will be discussed.

METHODS

A 25-year-old red pine (*Pinus resinosa* Ait.) plantation in Adrian Township and a portion of a 30-year-old jack pine and white spruce (*Picea glauca* [Moench] Voss) alternate-row plantation in Conmee Township were thinned in late winter and early spring, 1986 (Fig. 1). The objective was a 25% and 50% removal of the stems in Adrian and Conmee townships, respectively. A crew of four people, three with forestry technical education, were selected from the summer silviculture staff. Two had at least one season's experience with conventional harvesting and all had experience with brushsaw juvenile spacing work.

Trees were cut into tree-length, full-tree or shortwood portions at the stump and forwarded by the Swed Caddy, the Swed Caddy and trailer, or the skidder (Fig. 2). The shortwood was cut into 2.54-m lengths and the

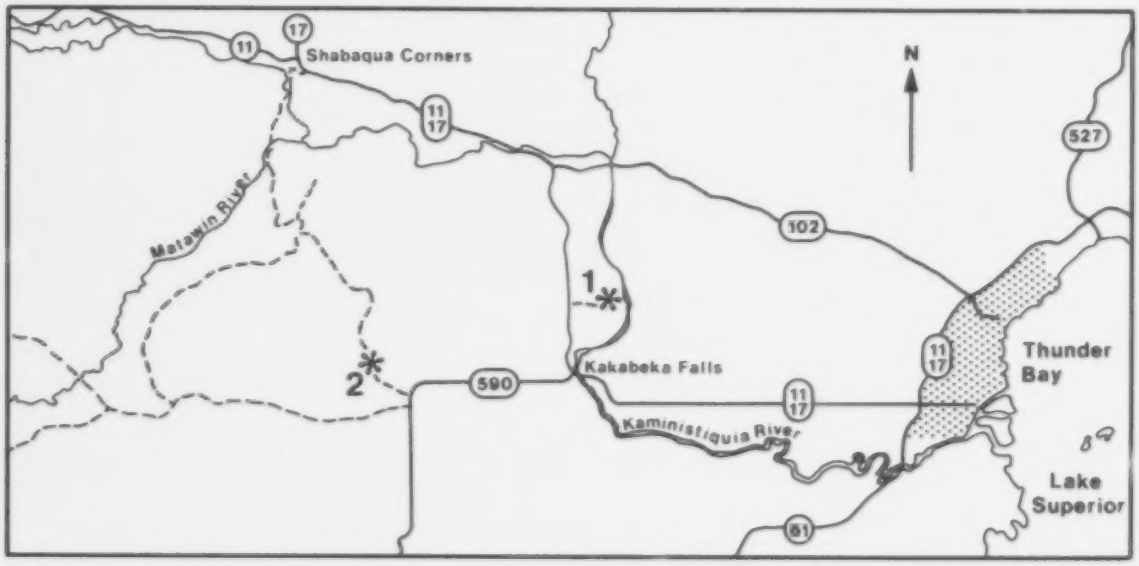

Figure 1. Location of operating areas for COFRDA thinning project.

1 Conmee Township - jack pine and white spruce alternate row plantation - 30 years
2 Adrian Township - red pine - 25 years

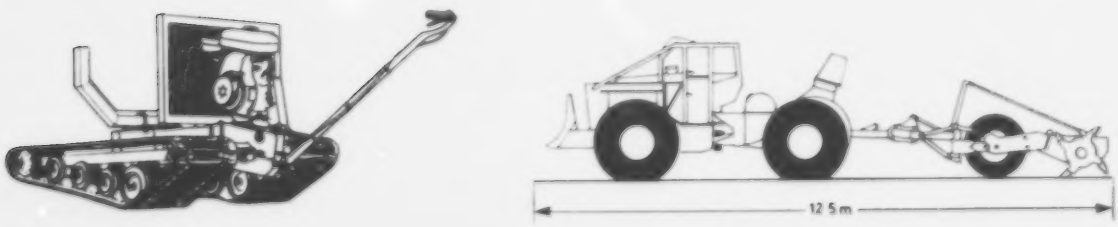

Figure 2. Swed Caddy and TJ-230 skidder (not to scale).

tops were a minimum of 10 cm; the full-tree and tree-length wood was bucked at the landing to shortwood dimensions. Each crew member recorded his activities (i.e., felling and delimbing, forwarding, tree marking, etc.) by 15-minute intervals to permit compilation of production figures. Individual pieces were butt-scaled at the landing. All wood measurements were on a solid cord basis (i.e., 85 ft^3 solid wood/cord, 2.4 m^3/cord).

RESULTS AND DISCUSSION

Thinning System

Table 1 is a production summary by thinning system. The increase in production in Conmee Township in comparison with that in Adrian Township was a result of shorter and straighter forwarding distances (200 m vs. 70 m), larger wood, flatter ground and better snow conditions. In addition, row thinning in Conmee (every other row) is more productive than low selective thinning in Adrian (removing approximately 50% of the stems to favor the removal of suppressed and inferior stems), as a larger work space is created. In fact, the skidder could only yard hand-piled shortwood close to the stand edge in Adrian whereas in Conmee it could enter the stand by backing into it where rows had been removed. Because both plantations were small, skid trails were not necessary.

Tree Size

The highest production was achieved with the Swed Caddy shortwood system in the Conmee jack pine operation. The large tree size is the most important contributor to the higher production rate. A clear trend showing the effects of tree size can be seen in Table 1, with the lowest production rate occurring in Adrian, where thinnings averaged 12 cm DBH. In Conmee, skid distances and terrain were identical between the white spruce and the larger jack pine. This direct comparison clearly shows the impact of tree size on production.

Shaw (1982) also shows that piece size is the most important factor influencing production in both clear-cutting and thinning operations. Limbiness and restricted work space may also contribute to a costly operation (Stiell 1975). Even thinnings in the order of 35 cm DBH generate harvest costs ranging from 110% to 180% of normal clear felling (Bacon et al. 1982). Seymour and Gadzik (1985) disagree, citing piece size as the only contributing factor to the high cost of thinning; however, their study emphasizes the importance of carefully planned skid roads but does not include the time required for layout and construction in the production figures.

Table 1. Production summary for felling, processing and forwarding combined, by location and system.

Location and method	System	Avg DBH (cm)	Production (m^3/prod./man hr)
Adrian red pine selective low-thinning from 2000 to 1500 stems/ha	Swed Caddy shortwood	12	0.13
	Swed Caddy tree-length	12	0.13
	TJ-230 yarding shortwood piles	12	0.13
Conmee white spruce row thinning from 2000 to 1000 stems/ha	Swed Caddy shortwood	16	0.28
	TJ-230 skidding full-tree	16	0.23
Conmee jack pine row thinning from 2000 to 1000 stems/ha	Swed Caddy shortwood	20	0.41
	TJ-230 skidding full-tree	20	0.31

Load Size

The heavy slash created by the limbed trees made the use of the Swed Caddy's trailer attachment impracticable; hence, load size was below optimum in Conmee. Our lack of experience was responsible for the slash problem. The feller must and can create a clear path for the Swed Caddy. Table 2 isolates forwarding production from the total production figures. The average load on both operations was below the manufacturer's rated capacity of 1 m^3/load. Still, the Swed Caddy outproduced the skidder, with production levels exceeding those reported in the Forest Engineering Research Institute of Canada (FERIC) test of the machine (Richardson and Folkema 1985). The same FERIC study quotes Swedish sources in which forwarding productivity as high as 2 m^3/hour is recorded. This rate is far superior to our best average of 1.19 m^3/hour. Clarke[1], in a red pine plantation near Thunder Bay, averaged 3 m^3/load by forwarding 4.8-m sawlogs with the Swed Caddy and trailer.

[1] F.R. Clarke, Assoc. Prof. of Forestry, Lakehead Univ. Sch. of For., Thunder Bay, Ont., pers. comm. 1986.

Production Levels

The highest overall production achieved was 0.41 m^3/hour in the Conmee jack pine operation (Table 1). The unusually deep snow conditions and the limby nature of the pine affected production negatively. Under better circumstances, 0.5 to 1.0 m^3/productive hour yielding 3 to 6 m^3/man day is realistic. On the basis of today's prices of about \$28.00/m^3 at the mill for kraft roundwood, profitable thinning with the Swed Caddy requires that one man produce 6-10 m^3/day. Is this feasible?

In Australia, production of 7-10 m^3/man day is possible (Kerruish and Sheppard 1982, Shaw 1982), but plantations there are less dense (i.e., boles are larger and the work force is highly skilled). As well, skidders are used 80% of the time. Seymour and Gadzik (1985) report an average of 10 m^3/man day in thinning 16-cm tree-length balsam fir (*Abies balsamea* [L.] Mill.) with skidders from carefully planned skid trails. It will be a challenge to achieve this level with the Swed Caddy.

Table 2. Forwarding production rates by location and system.

Location and method	System	Load size (m^3/turn)	Production (m^3/prod./man hr)
Adrian red pine selective thinning (low)	Swed Caddy shortwood with trailer	0.68	0.61
	Swed Caddy tree-length without trailer	0.80	0.65
	TJ-230 yarding shortwood piles	0.47	0.52
Conmee white spruce row thinning	Swed Caddy shortwood without trailer	0.48	0.99
	TJ-230 skidding full-tree	0.26	0.25
Conmee jack pine row thinning	Swed Caddy shortwood without trailer	0.47	1.19
	TJ-230 skidding full-tree	0.46	0.62

To produce 6-10 m^3/man day with the Swed Caddy requires highly motivated and skilled workers cutting in ideal plantations or natural stand conditions. Thinnings should average four pieces per tree and yield 0.22 m^3/tree (with wood slightly greater in DBH and 2 m taller than the Conmee pine). Plantations should be clean, with level terrain, and lie within 100 m of good road access, no more than 150 km from the mill. With wood this size, tree-length skidding may be more cost effective than the Swed Caddy system.

Cost

Felling merchantable stems with chainsaws in a thinning operation does not necessarily require removal of the wood. For example, jack pine in the Conmee plantation could be felled at a cost of $300 to $500 per ha. These figures are based on the assumption that 75 trees per man hour are felled. Seymour and Gadzik (1985) and Kofman (1985) show that felling productivity with trees of similar size can be as high as 100-150 trees/hour; hence, the cost of felling can be further reduced. A doubling of the production levels achieved in the Conmee jack pine operation would result in felling, processing and forwarding costs totalling about $2,900/ha (Table 3). Wood revenue, less hauling costs and crown dues, would lower the net cost to $1,300/ha. Hence, if thinning is viewed solely as a silvicultural activity designed to bring higher returns at the final cut, merchantable wood may be cut and left to rot because the costs of extraction are prohibitive. This merely advances the natural outcome of events typical of a stand self-thinning with age.

Utilization

If mill utilization requirements change and wood prices rise above the current $28/$m^3$, stands may be thinned profitably, if labor and fixed costs remain static. Olsson (1985) shows recoverable volumes increased by 20-60% when tree length to a 7-cm top or full-tree utilization replaces shortwood systems. Another alternative might be to create products of higher value from the thinnings at roadside by setting up small portable sawmills.

Work Force

The experience level of the work force was fairly low. Bankes (1982) showed that formal training can increase thinning production levels by as much as 75%. It became

Table 3. Cost per ha and solid m^3 for extrapolated production levels (0.8 m/prod./man hr) for the Conmee pine operation.

Activity	Cost	
	$/ha	$/$m^3$
Felling	165.54	2.07
Processing	1,252.23	15.65
Forwarding	1,486.73	18.58
Total roadside cost	2,904.50	36.30
Roadside revenue (mill price less transport cost and crown dues)	1,600.00	20.00
Net cost	1,304.50	16.30

clear during the project that careful work planning and layout and the use of skilled, experienced labor for felling could make a significant difference.

It should be emphasized that the project did extend the time of employment for staff. This had a positive effect in the following season's silviculture program because of staff continuity. Some companies may be satisfied to break even on thinning operations to maintain a consistent work force.

Motivating the work force with piece-rate incentives would also boost production; however, piece rates must recognize the constraints on production. Seymour and Gadzik (1985) describe methods for adjusting piece rates to reflect the lower production associated with thinnings.

Mechanization

Finally, development of mechanized equipment may overcome the individual tree handling and processing associated with chainsaws used in this study. Many clear-felling operations are becoming partially or totally mechanized both locally and internationally in response to high labor costs and smaller piece sizes. Many mechanical thinning systems have evolved recently, but stand conditions and stand distribution must be clearly defined before systems are tested in this area. Mechanized systems would have been uneconomical in Adrian and Conmee because the plantations were too small.

Although we did not attempt it, the Swed Caddy can be used to prebunch wood (i.e., concentrate wood along trails 100-200 m apart and forward the wood by means of large conventional forwarders). A "two-step" operation with labor-intensive, low-investment prebunching and highly efficient, high-investment final forwarding for up to 2,000 m before reaching a truck road can be utilized.[2]

[2]J. Hermelin, Director of Forestry Extension Services, Dep. Nat. Resour., New Brunswick, pers. comm. 1986.

SUMMARY

The Swed Caddy consistently outproduced a small skidder in three thinning operations in late winter of 1986. The skidder was tested mainly under a full-tree system whereas the Swed Caddy was used mainly as a shortwood system. Tree-length systems could double skidder production; however, the small capital outlay and low maintenance and operating costs make the Swed Caddy more attractive. Late fall and winter thinning operations stabilize the silviculture work force by extending their employment period. Production levels of 3 m^3/man day are possible with the Swed Caddy but this rate must be more than doubled to make the operation profitable. Highly skilled and motivated workers would require large wood (20 cm DBH+), averaging four pieces per stem growing on level terrain within 100 m of good access roads relatively close to the mill, or a "two-step" prebunching operation within 2,000 m of a truck road. Alternatively, thinning operations in suboptimum conditions could be viewed as a silviculture treatment alone, in which the stems are felled but not removed.

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ACKNOWLEDGMENTS

We wish to acknowledge the assistance of Joakim Hermelin, Director of Forestry Extension Services, Department of Natural Resources, New Brunswick; Mike Folkema, Group Supervisor, Forest Engineering Research Institute of Canada, Montreal; F.R. Clarke, Associate Professor, and Dr. W.H. Parker, Professor, both of the School of Forestry, Lakehead University, Thunder Bay, Ont. Funding was provided through the Canada-Ontario Forest Resource Development Agreement.

HIGH TECH AT THE DESK

HIGH TECHNOLOGY AND TIMBER MANAGEMENT PLANNING

J.T. Kus
Timber Sales Branch
Ontario Ministry of Natural Resources
Toronto, Ontario

Abstract.—Timber management is one of several resource management activities administered by the Ontario Ministry of Natural Resources (OMNR). Although harvesting activities have been going on since the early 1800s it was not until the Crown Timber Act was passed in 1953 that forest management plans, operating plans, and annual plans became mandatory in Ontario and subject to review and approval by OMNR. It was also about this time that the first extensive surveys of Ontario's timber resources began. Since then, forestry has undergone many changes. The development of modern harvest technology to produce wood and deliver it at the mill at minimum cost began with the introduction of mechanized harvesting, road construction and wood loading and hauling equipment. In addition, there have been developments in electronic data processing technology, particularly in the last 5-10 years. This paper examines how these latter developments have affected forest management and suggests what we can expect from "high tech" in the future.

Résumé.—L'aménagement des ressources en bois compte parmi les diverses activités d'aménagement des ressources du ministère des Richesses naturelles de l'Ontario (MRNO). Bien qu'on exploite les forêts depuis le début du XIX siècle, ce n'est qu'à l'adoption de la Loi sur le bois de la Couronne, en 1953, que les plans d'aménagement forestier, les plans d'exploitation et les plans annuels sont devenus obligatoires en Ontario et ont été assujettis à l'étude et à l'approbation du MRNO. C'est également à cette époque qu'on a entrepris les premiers inventaires détaillés des ressources en bois de la province. Depuis, le secteur forestier a subi de nombreux changements. La mécanisation forestière, la construction de routes et les engins de chargement et de débardage ont modernisé les techniques d'exploitation, permettant de produire le bois et de le livrer à la scierie, à des coûts minimes. De plus, à ces facteurs, il faut ajouter la révolution informatique des 5 à 10 dernières années. Dans la présente communication, on étudie comment ils ont influencé l'aménagement des forêts et on laisse entrevoir ce que la haute technologie nous réserve pour l'avenir.

Forest management is defined as "the practical application of scientific, technical and economic principles of forestry"[1]. It consists in:

* providing access to harvestable timber
* harvesting timber for transport to wood processing facilities
* renewing the timber resource by
  - site preparation
  - regeneration by natural or artificial means
* maintaining the timber resource by
  - tending
  - protection

In carrying out any one of these activities, both biological and economic factors must be considered. Often these factors can work against each other and force the manager to weigh a decision on the basis of his or her own knowledge alone. The objectives of forest management planning are to predict and schedule man's intervention in the forest environment and to determine the level of intervention that should take place.

Management is the process of:

* planning
* organization
* implementation
* control

Planning involves the establishment of organizational goals and the designing of programs for achieving them in a systematic manner. This requires decision making in the setting of goals and objectives and forecasting in the development of support plans. *Organization* requires leadership in the delegation of tasks and the resolution of conflicts or concerns, as well as the ability to deliver in a timely manner. *Implementation* also requires leadership. Guidance and supervision of workers who carry out the plan are fundamental in meeting stated objectives. *Control* involves record keeping. Keeping records to measure one's performance against established standards is essential to the achievement of goals.

Each of these steps in the management process involves *analysis*. Simply speaking, analysis is the process of converting data into knowledge, as shown by this simple flow chart:

Data → Information → Knowledge

The intermediate step is information creation. This process can best be illustrated by the following example. The Forest Resources Inventory (FRI), Ontario's provincial inventory system, classifies forest land according to species and their attributes (age, height, etc.). Uniform mixtures of these attributes create stands. Stands in a management unit can number as many as 25,000.

It would be impossible to understand the condition of this management unit if one did not summarize the data in some way. In FRI reports these data are organized in a readily comprehensible form. On the basis of the results obtained, one can visualize and quantify the type and condition of a specific forest. This analysis process helps to establish a better understanding of the results obtained. It can identify parts of the equation most sensitive to inputs and those over which we have no influence. Analysis also improves one's understanding of the choices among alternatives. Only by comparing different options and considering both economic and biological factors can one determine the actions necessary to meet one's objectives. Only by analyzing actual as opposed to planned achievements can one identify remedial actions needed to meet the original targets and actions to avoid in the future. In this way, analysis becomes a learning exercise, and one hopes that future planning can be improved as a result of the experience gained.

Now that we have an understanding of what forest management is and of the steps required to make it effective, a short introduction to "high tech" is in order. An understanding of the basics will enable you to use "high tech" to assist you in your forest management planning.

Computer equipment comes in many shapes and sizes. Whether large or small, computers all operate on the same fundamental principles. Perhaps the biggest development in this field in recent years is the personal computer (also referred to as the "micro"). These small computers are currently capable of executing sophisticated computing tasks that, until recently, required machines that cost millions of dollars and filled entire rooms.

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[1] p. 87 *in* Anon. 1953. British Commonwealth Forest Terminology. Part I.--Silviculture, protection, mensuration and management, together with allied subjects. Empire For. Assoc., London, Eng. 163 p.

In fact, some of today's micros exceed the capabilities of last year's "minis" or "main frames".

Any computer is an information or data processing system. This means that a computer accepts data, performs a set of operations or instructions with the data and displays the results. The data are often referred to as "input" while the results are called "output". Computers also permit the processing of large volumes of data or complex patterns of information that would otherwise be difficult to organize and understand.

The principal elements of a computer system are:

* central processing unit (CPU)

* random access memory (RAM)

* secondary storage

* input/output devices

The *CPU* is the heart of any computer system. It determines the speed and accuracy of computations and the rate at which information moves around. On the basis of a sequence of electrical on/off signals it is capable of only simple arithmetic and logical operations such as data comparisons. *RAM* (the main memory) contains the programs and data that are being processed by the CPU at any given time. Therefore, the larger the RAM the faster the process. *Secondary storage* is usually provided by floppy discs, magnetic tape or hard disc drives. They "store" data until needed, whereupon they are "loaded" into the CPU to be executed in RAM. The links between man and machine are through the *input/output devices*. Data and programs are entered via the keyboard (input), at least initially, and displayed on screens, prints and plotters (output). The components listed here are usually referred to as "hardware" in computer jargon.

If the CPU is referred to as the heart, then the operating system is the heartbeat. This "software" brings the computer to life. As well as ensuring that the hardware is functioning correctly, it loads a set of system control programs into memory every time the machine is turned on. It is this program that allows the user to enter and execute commands. Programs, which are sometimes referred to as applications, are a series of these executable commands.

Perhaps the real advantages of microcomputer technology are the programs it runs. The "user friendliness" of some programs relates directly to their popularity. It is this characteristic of programs that can make laymen like me less apprehensive when sitting in front of them. Computer applications fall into four main types:

* storage and retrieval

* analysis

* display

* communications

Visions of an old file cabinet and a card index emerge when one speaks of *storage and retrieval software*. In fact, software does no more than the cabinets of yesterday and database managers are the file clerks. A database is a collection of interrelated data organized to facilitate efficient inquiry. Database managers use a systematic approach to storing, updating and retrieving information. Some database managers allow for multiple, simultaneous inquiries directed to the same file. Storage of data electronically also saves on physical space. The compactness of the equipment and the speed with which data can be retrieved are two of the most popular features of computers.

Analytical software provides the "number crunching" capability for which computers have become known. Analytical programs can be either custom written with languages such as Fortran or produced by using software packages such as the Saturn Calc spreadsheet. Either type contains sets of instructions that a digital computer must execute to get a specific result. Spreadsheets are electronic two-way work sheets (matrix) that have an added advantage in that they require little or no formal computer training on the part of the user. Often menu driven, they take care of many "behind-the-scene" details with which professional programmers must be concerned.

Computer technology can also assist the user in presenting results. Word processed or pictorially represented information, displayed in clear and concise format, frees the viewer from the need for further interpretation and thereby makes him more receptive to the messages being conveyed. Fast, easy-to-use packages are more attractive to the user as well.

Computers are also valued for their communications capabilities. In offices, micros with attached modems are quickly replacing standard Telex machines. Modems permit the transfer of data between machines on conventional telephone lines (electronic mail). They also permit acquisition of remote data, which can prevent costly duplication of effort and improve information accessibility.

The mandate of the Management Planning Section of OMNR's Timber Sales Branch is to assist, where possible, and to monitor the preparation of timber management plans. We also review and recommend the approval of plans to the Director of the Timber Sales Branch. We concentrate on long-term wood supply and take on special assignments as necessary. Our short time frames necessitated development of computerized methodologies. Today, we rely heavily on the methodologies we developed in the past, but we are continually examining others.

One of the first tools developed by OMNR was the Ontario Wood Supply and Forest Productivity (OWOSFOP) model. Like all good things, it was borrowed from elsewhere (New Brunswick). Customized for the Forest Management Agreement program, it became the standard methodology for calculating the Maximum Allowable Depletion (MAD), formerly known as the Annual Allowable Cut. For those who are not familiar with the model, the 5-year MADs are calculated on an area basis. The model also estimates associated gross total volumes (all species) on the basis of the FRI data initially entered. Our problem was to quantify the net merchantable volumes realized by harvesting a particular area. A spreadsheet program was developed that used the outputs of OWOSFOP and the FRI reports and calculated the net merchantable volumes by species for all of the forest units present on the management unit. This procedure provides a standard method for replying to the requests we get on a regular basis. The figures are then verified against past scaling and cutting returns.

The advantages of this system are obvious. A wood supply problem that may have taken days to solve can now be handled in a matter of hours. The system also supplies additional information that would otherwise not be available for use in the decision-making process.

Spreadsheets are also valuable "ad hoc" tools as they can be quickly created and/or modified to meet one's needs. Taking advantage of their import/export capabilities, we have used them to combine data files for other programs. Integrated packages such as Lotus 123 provide an additional benefit in that they can produce graphics without having to re-enter data.

With the implementation of the new planning process and the submission of the Class Environment Assessment, there has never been a greater need for status and accomplishment monitoring. Forest Management Agreement annual reports have always been entered into a database for record-keeping purposes. Not only do these systems maintain the accuracy of the initial input but they also allow for summaries in a variety of different formats.

The FRI is perhaps one of the best known databases in the province. Although this database has traditionally been maintained on the Queen's Park mainframe computer, current developments such as the FRI Data Entry System (FRIDES) has made it possible to update data by using field office micros. An additional advantage of this breakthrough is that it has made possible the production of customized reports using database packages. For example, on a sample management unit, spruce grows primarily on upland or on lowland sites. Each of these sites has different growth characteristics. The lowland spruce type is found mainly on organic sites and therefore consists primarily of black spruce (60% or more), and has minor components of cedar and/or larch. Upland sites, on the other hand, could conceivably include all other combinations found. These stands can be distinguished from one another easily by using a database package and querying the species composition. Once the stands have been distinguished, information on age class distribution by site class and basemap can be summarized quickly. In this manner, FRI data can also be used to identify potential modified-cut areas, to separate white spruce from black spruce, etc.

Stand data have also been used to compare past and proposed harvest areas. On the basis of past scaling returns, future yields can be forecasted or compared. The dissemination of FRI data has also spawned other applications. For example, the North Central and Northwestern regions have developed the "TMP Toolbox",[2] which should prove to be a useful tool for the management forester.

With the proliferation of different hardware packages came the need for compatibility. Some compatibility can be gained by using a communications package called KERMIT (an acronym for KL10 Error-free Reciprocal Micro Interconnect over TTY lines). The package has been designed to allow for the transfer of ASCII characters (data) from one machine to another. The machines need not be part of the same operating system.

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[2] The Timber Management Planning Toolbox is a digital professional-based management planning system that allows the forest manager to prepare reports on the management unit inventory, to prepare allocations and to record depletions.

And what of the future? Part of the future is here today. We can expect to become more adept at using computers to assist us in our management tasks. We can also expect to see the development of new computer applications and the replacement of old ones. The remainder of this paper is intended to stimulate the mind and unlock the doors to innovation, for the possibilities are endless.

We live in an age in which we are continually being asked to do more with less. Whether it be the assembly of widgets or the construction of a road, a fixed level of inventory is the norm. There is currently available a software package called "What's Best". It is an add-on to the LOTUS spreadsheet. With the spreadsheet designed in a particular manner, the add-on becomes a linear programming model and optimizes the functions within the limits identified. For example, suppose you are given x units of A, y units of B, and z units of C. If you have the option of making one of two products, each requiring different amounts of input and each with different profit margins, What's Best can optimize or minimize any part of the equation in mere seconds. Although linear programming is not new, it has never been available to the non-academic in such a "canned" package. The possibilities for forestry include stock production, investment dollars, and wood-flow modelling, to name a few.

Word processing is one of the better known applications of computer technology. Almost every office has a word processor. Once entered, reports, letters and documents quickly become identifiable only by obscure filenames, which eventually lose all meaning. the only way to find a document is to search through the files until it emerges. A package called ZyINDEX offers "full-text" information retrieval. It uses any word, phrase or number contained in a given document to search automatically for that document. This package not only finds the document but also displays the paragraph with the original search phrase highlighted. The user can then extract any portion of the file and transfer it to another file in seconds.

In the near future, literature searches will not be as painful as they once were. Management plans will be produced electronically, with quick reference to particular sections. Environmental assessment hearing transcripts will be perused systematically by subject. The possibilities are endless.

You may ask how all those documents can be entered into a machine efficiently. At OMNR's Timber Sales Branch, we are in the process of acquiring an optical character reader (OCR). This device, similar to a photocopier, scans a page and creates an ASCII character file of the page. This file automatically becomes a word processing file ready for editing or scanning with the aid of a package such as ZyIndex. We are also examining other applications of OCRs. The new Timber Management Planning Manual is thorough in its annual reporting requirements. We are examining the possibility of using OCRs and direct data transfer for automatic loading of data into a database manager. This will eliminate the rekeying of data and any errors associated with it. With OCRs used in conjunction with text editors and retrieval systems, planning documents can be reviewed electronically.

One of the main reasons personal computers have become so popular is that there is a great assortment of games available for use with them. Their popularity stems from the advanced graphics incorporated in them. However, graphics has also become important in professional and business applications. The ATLAS advanced mapping package is one such application. Heralded as a strategic locations planner, it is capable of creating shaded or color-coded thematic maps for use in analyzing and presenting any kind of geographic data. It is composed of a boundary file containing the coordinates of the polygons entered by means of a digitizing tablet. Each polygon has a unique identifier linked to a data file. Information can be imported from other packages such as Lotus and D Base. We are considering the possibility of using this package to record the status of various items of concern. We are also examining the possibility of linking to FRI inventory summaries by mapsheet as a means of assisting in wood supply analysis. Although this package is by no means a geographic information system, it does show potential for less sophisticated applications.

The final item I wish to discuss is the geographical information system. This system will eventually be capable of merging "layers" of information, and will be an invaluable tool in the area of prime site management. The ability to show relations between FRI data, soil, wood flow, access, etc., will facilitate the development of all-encompassing planning strategies. The system will become particularly useful when we are dealing with finite resources such as investment dollars.

All technological developments to date have one thing in common. The decision-making process rests with the computer user--in our case, the management forester. He or she is ultimately responsible for the management of the resource and the decisions involved. Computers can only facilitate the decision-making

process. Because we are now able to examine alternatives we hope, ultimately, to make better decisions.

I have not attempted to identify acceptable as opposed to unacceptable applications of "high tech". Any application that can assist you in meeting *your* objectives is well worth the investment. At the same time *you* are the only obstacle in developing applications.

With an open mind and a little imagination you, too, can put "high tech" to work at your desk.

The last point I would like to leave you with is this: if your only goal is to save money, don't waste it on computers. If you wish to improve decision making and make more effective use of your time and limited funds, then you cannot afford to be without "high tech".

FOREST MANAGEMENT AT ABITIBI-PRICE: AN EXAMPLE OF STRATEGIC COMPUTER MODELLING

N.J. Saltarelli
Superintendent of Forestry and Control
Abitibi-Price Inc.
Iroquois Falls, Ontario

Abstract.—Sound management of forest fiber resources begins with a clear management philosophy or policy. Strategy formulation is the second step: understanding what the objectives are and where, when, why and how those objectives will be accomplished. Forest dynamics over lengthy periods and the multiplicity of options available to the forest manager dictate the use of computer simulation for efficient formulation of strategy. This paper presents an example of strategic computer simulation on an operational level under the constraints of the Ontario Forest Resources Inventory and regulatory systems.

Résumé.—L'aménagement avisé des ressources ligneuses de la forêt commence par l'exposé d'une doctrine ou d'une politique claire d'aménagement. Vient ensuite la formulation de la stratégie: comprendre les objectifs en jeu et où, quand, pourquoi et comment ces objectifs seront réalisés. La dynamique forestière, qui s'étale sur une longue période, ainsi que la multiplicité des options auxquelles l'aménagiste peut s'adresser imposent l'emploi de la simulation par ordinateur pour la formulation efficace de la stratégie. Cette communication donne un exemple de cette simulation de la stratégie par ordinateur, à l'échelle opérationnelle, compte tenu des contraintes de l'inventaire des ressources forestières de l'Ontario et du régime réglementaire auquel sont soumises ces ressources.

INTRODUCTION

Our forest management strategy at Abitibi-Price is flexible; it changes with time and circumstances, as economics and technology dictate. At the same time, we strive to maintain strategic stability through well established goals. The key to any workable strategy is knowing the desired outcome--what is to be accomplished and when. Now, that may seem like an absurdly obvious statement, but it is surprising how many forest managers are operating with neither a clear objective nor a strategy by which an objective may be realized.

One of the main difficulties in Canadian forestry has to do with time. Foresters are fond of comparing silviculture with agriculture and, although there are valid parallels, we have a tendency to gloss over the great gulf between relative crop rotations. A farmer knows that by 15 September he should get 10,000 bushels of corn out of his north 40, but the typical forest manager will volunteer only a fuzzy approximation of when his cutover areas will be ready to harvest, and an even fuzzier estimation of the volumes they may yield. (He'll probably be dead by then anyway, so he may not even care!).

Wayne Gretzky is credited with saying: "I don't pass the puck to where my teammate is, I pass it to where he is going to be".[1] A similar expression could be applied to many

[1]Gretzky, W., the Great. 1986. Captain, Centre and All-around Wunderkind, National Hockey League, Edmonton Oilers (as quoted by the Financial Post).

activities, including the management of forests, and if the objective can be likened to a moving target, then it is necessary to plot not only its trajectory, but also that of whatever we use to intercept it.

A clear conception of where we are and where we want to end up is essential. A well defined strategy that will take us there, and the ability to develop it, are also essential. These things begin with a forest policy.

CORPORATE POLICY AND OBJECTIVES

Policy, by definition, does not provide a crisp, well defined strategy--it merely points in what is perceived to be the right direction. Abitibi-Price's forest management policy, for example, contains the following statements:

> *"We believe in and are committed to definite principles and practices of sound forest management. Furthermore, we are confident that through such management, the forests entrusted to us will continue to provide sufficient fibre and other tangible and aesthetic benefits to meet the short and long term needs of both the company and society.*
>
> *It is the policy of Abitibi-Price to:*
>
> - *apply the principles of responsible forest management to the forests under our jurisdiction to ensure a continuous long-term supply of quality fibre to our dependent manufacturing plants,*
> - *work cooperatively with government at all levels toward improved resource and environmental management,*
> - *support the principle of multiple use of the forest land and recognize the importance of preserving the environment."*

The main objective, then, is to provide benefits to company and to society through responsible forest management in concert with government. The policy goes on to say how the objective may be attained: through landbase tenure, forest protection, reforestation, inventory control, research, tree improvement and multiple use. Now that covers a lot of bases, but it is still a good solid starting point. This, then, is the background to the development of our strategy, and from here I'll take the Iroquois Falls Agreement Forest as a representative case in point.

Our main Forest Management Agreement (FMA) objective is fiber supply, more specifically, a constant supply. To achieve this objective, we have undertaken a renewal program that we believe will ensure the future availability of wood. The main thrust of this program is planting at a mean annual level of 5 to 6 million trees on 60 to 75% of our cutover area. That's our direction in a nutshell; how we got to that point is a more complicated story.

FUNDAMENTALS

The Iroquois Falls Forest is located within the Great Northern Claybelt of northeastern Ontario. It is a piece of real estate covering 9,500 km^2, of which 7,400 km^2 are productive forest. Management of this resource is dedicated to the supply of raw fiber to our newsprint mill at Iroquois Falls proper.

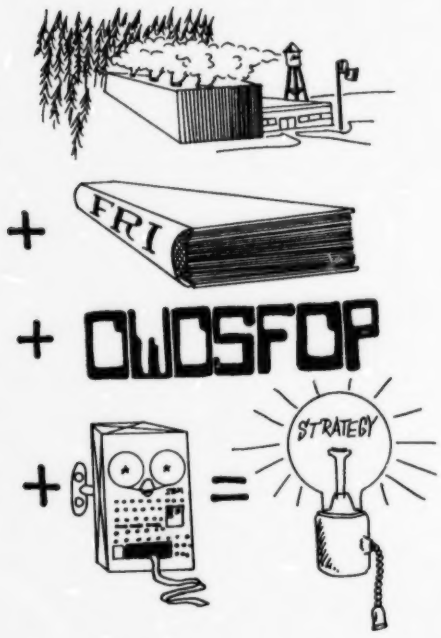
Of the three currently operating, our new Number 8 paper machine is by far the largest. It is a $132 million investment in the future, vulnerable to and dependent upon a stable wood supply. Number 8 produces a sheet 9 m wide at speeds averaging well over a kilometre a minute, yielding on average over 500 tonnes a day of high-quality, twin-wire newsprint. It alone consumes more than 1,400 m^3 of wood a day--about 10,000 trees from about 15 ha every day, 7 days a week. As well as this behemoth, there is a distinct possibility that Number 9 will be built in the not-too-distant future. This is the starting point--this paper machine has been paramount in determining the direction and the scale of forest management at Iroquois Falls.

The vehicle we used to arrive at our conclusions was an IBM 4341 mainframe, capable of handling the massive datasets common to forestry applications at speeds nearing 1.1 million transactions a second. Our main database was the Forest Resources Inventory (FRI), not by any means a flawless item, but the best we have to work with and one that we are bound to by association with crown forest management in Ontario. We are also bound to a single method of regulation, known affectionately as OWOSFOP, the Ontario WOod Supply and FOrest Productivity model produced by the lads in the MacDonald Block. OWOSFOP tells us what we can cut and when, and what will happen if we do such-and-such a thing; it determines our surpluses and predicts our shortfalls. It's a marvellously complicated model that simulates

the consequences of one's management decisions, but for the purposes of determining scale of forest management, it is not complicated enough.

To summarize:

BASIC RECIPE



1) We have our starting point, a hungry mill to feed and the real estate upon which we will produce our furnish;

2) we have our FRI that tells us what we have now to work with (that's arguable, but another subject entirely);

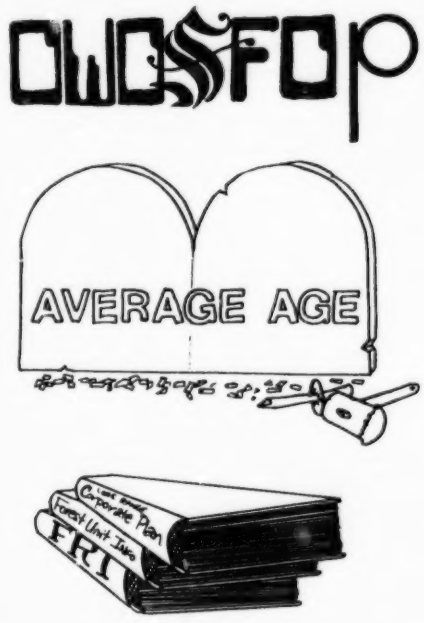
3) we have OWOSFOP which, at least for the time being, steers us unswervingly in a singular regulatory direction;

4) and we have a superbly powerful computer that allows us to perform several years' worth of calculations in a few minutes.

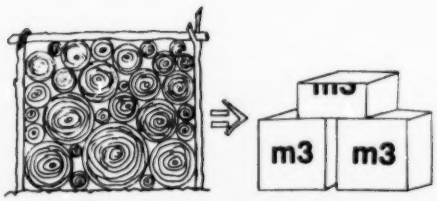
SIMULATION

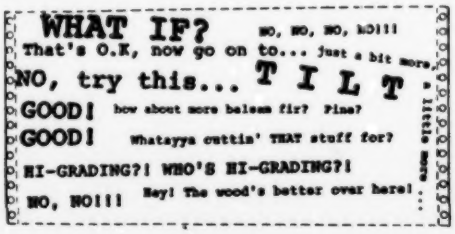
What we did, then, was bastardize OWOSFOP; we bent it to suit our immediate needs while maintaining its integrity. The method of regulation, i.e., Average Age Allowable Cut, remained intact. What was manipulated was the information that was fed into the equation. We also enhanced the simulation process to perform a few extra maneuvers, ranging from something as simple as metric conversion to complex harvesting optimization. We also tampered with the progression of uncut age classes. OWOSFOP will allow uncut stands to grow older indefinitely--our enhancement "nature-harvests" much of the old stuff.

REPROGRAMMING



ENHANCEMENTS




WHAT IF?
NO, NO, NO, NO!!!
That's O.K, now go on to... just a bit more,
NO, try this... T I L T
a little more...
GOOD! how about more balsam fir? Pine?
GOOD! Whatayya cuttin' THAT stuff for?
HI-GRADING?! WHO'S HI-GRADING?!
NO, NO!!! Hey! The wood's better over here!

Another feature was a two-tiered rotation age/forest unit regime, one for the natural forest and another for the artificial forest. Each tier, as well as having its own rotation age, had its own volume per unit area and harvesting selection priority level. To approximate the real world more closely, we programmed two harvesting options. The first adheres strictly to the FMA concept of surplus declaration and subsequent harvest; where we do not harvest the full Annual Allowable Cut, the computer assumes that the balance is allocated and taken by a third party. The second option assumes that surplus volumes are not taken by a third party but are allowed to grow older (and, of course, fall down and die if allowed to grow old enough).

We loaded the computer with the FRI file, forest unit information, Not Satisfactorily Regenerated (NSR) treatment regime and long-range fiber procurement plan and asked it to indicate the required scope of our renewal program. The computer model allowed us four basic options:

1) planting absolutely every hectare that is harvested and plantable;

2) managing the forest so that future cuts could be taken solely from the artificial forest where, ostensibly, volumes would be more concentrated;

3) managing the forest so that yield is sustained from both the natural and the artificial forest components;

4) not managing the forest at all.

For each of the four options, two simulations were executed, one for each of the surplus options. In all, eight working simulations were executed, each one optimizing harvesting and renewal of 14 distinct forest units (seven natural, seven artificial) over a period of 140 years. Each simulation demanded the approximate equivalent of 15 man-years of calculations. The results of the eight supply simulations were plugged into a cost analysis model, producing eight economic impact "scenarios".

STRATEGY

The numbers provided by options 1 and 4 made them essentially non-options. We never expected them to be anything else, actually, but they served to define either extreme of the spectrum of possibility.

Planting everything would prove to be astonishingly expensive and would result in a glut of fiber so great that there could be no hope of ever using it all. (This conclusion, of course, is based on the assumption that the Iroquois Falls Forest will not be called upon in future to support a far larger piece of the Northern Region's industrial base.)

Doing nothing had a predictable outcome--a steady, relentless decline in available volumes and allowable cut, and we would be out of business in 60 years or so.

Having dispensed with these options we set ourselves to examining the two remaining options with an eye to adopting one of them as the management basis for the second five-year term of our FMA. In fact, we waffled between them; each seemed to score a point here, lose a point there. In the end, it was decided that we would adopt option number 3 as the benchmark for the new term--sustained yield from the forest as a whole rather than from the artificial forest alone. The simulation told us that this could be accomplished by planting 5.0 million trees a year, with natural regeneration management employed for the balance of what is harvested. Option 3 allows present harvests to continue indefinitely as well as providing for possible increases in demand. It allows for relative independence from non-limit furnish should this source dry up in future. It allows, in short, sustained supply of forest products from the mill at Iroquois Falls, the raison d'être of the FMA.

Option 2 did this as well, only more so. Managing the forest to eliminate dependence on its natural component was attractive, but economically inferior to managing for sustained yield over the entire forest. While it was true that we could harvest all of our future requirement from a smaller area, the ultimate cost on a unit volume basis would be greater, and that meant that this option was less efficient. Responsible forest management dictates that we as managers do our jobs in such a manner that the most good is realized by the greatest number for the least cost.

RATIONALE

Now, it's always advisable to quote those who have a reputation for knowing something about what you are talking about in order to lend credence to your viewpoint. And who knows better what I am talking about than Ken Armson?

"Investment in regeneration, which is the second step in forest management after logging, demands a conscious decision about what, where and how to regenerate. It should not be a response to the plea 'to regenerate every acre harvested'. For the most part, that will happen naturally, and a blanket investment would be wasteful.

Attempts to codify such beliefs that for every tree cut a new one should be planted or that all areas harvested shall be planted are therefore inappropriate if the forest is to be managed as a sound investment, not only for timber production, but also for other uses."[2]

We are managing a resource that is required by both company and society, with funds provided by both parties. With the information, expertise and options available to us, there could be no more responsible direction than that taken.

DISCUSSION/CONSTRAINTS

So that's how the forest management strategy for the Iroquois Falls Forest came to be. Most of you will see the potential flaws:

- What if the FRI, by which our simulations are so heavily weighted, is grossly inaccurate?

- What if our assumptions (concerning rotation ages, forest units, yields, demands, surpluses and so on) are wrong?

- What if our model's optimization of forest unit harvest is unrealistic, based as it is on a regulation method that doesn't mirror the real world?

- What if there is a major revision of the Region's industrial base?

- What if the Iroquois Falls Forest landbase should be much reduced, whether by design or by calamity?

All of these questions are valid, yet unanswerable, and they indicate why our strategy must be flexible. We have already produced a more precise simulation model that looks at distinct, mapped harvesting areas over a period of 1 to 20 years, but it is, like our OWOSFOP enhancement, dependent on scientific assumptions rather than scientific fact. We have taken the "5 million trees per year" target as one that is not graven in stone but as a baseline that may be adjusted year by year according to prevailing circumstances. While we planted at baseline in 1985, 5.6 million trees were planted this year (1986), and it looks as if we will need closer to 6 million next year, although possibly we will be able to taper down in the direction of baseline toward the end of the decade. All of these calculations are based on our present set of numbers. We will have a new FRI in 1989, when we will rerun our simulations and adjust our strategy accordingly, and that is the most we can expect to do until we're older and wiser.

The rest? It's the old problem of time. Only time can give us all the answers, and those answers will be greatly influenced by what we have or have not done beforehand. It is our responsibility to manage the forest effectively and efficiently using the most up-to-date tools at our disposal, including, of course, state-of-the-art computer simulation. Forestry is entering a new era, it's true. Yet there can be absolutely no doubt that exercises such as I have just described will seem coarse and primitive in comparison with what is yet to come.

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[2]Armson, K.A. Executive Coordinator, Forest Resources Group, Ontario Ministry of Natural Resources. *In* "The Difficulty in Life is the Choice" (speech to the Ontario Forestry Association).

MODELLING FOREST MANAGEMENT

H.D. Walker, Assistant Professor
Forest Management Science
Centre for the Application of Resources Information Systems
School of Forestry, Lakehead University
Thunder Bay, Ontario

Abstract.--Forest management is characterized by large spatial and temporal scales. Consequently, managers cannot effectively choose silvicultural alternatives for each stand within a forest, without using simplified representations (models) of forest systems. Models permit the expected forest-level effects of alternative silvicultural treatments (including harvesting) to be observed readily. However, skill is needed to ensure that models achieve an adequate compromise among transparency, generality, accuracy, and precision. Brief reviews of two recent applications of computer modelling to forest management planning illustrate how models may be used. In future models are expected to provide better reflections of forest systems, and to be more readily available to and used by forest managers. As model use increases, the need for silviculturally skilled managers will not decrease. Rather, models will provide managers with improved opportunities to focus their silvicultural knowledge, and to control forest development over time.

Résumé.--L'aménagement forestier se caractérise par sa grande échelle spatio-temporelle. Il s'ensuit que les aménagistes ne peuvent pas choisir en toute connaissance de cause entre les possibilités sylvicoles propres à chaque peuplement d'une forêt sans user de représentations simplifiées (modèles) de la forêt. Ces modèles permettent d'observer en accéléré les effets prévus de divers traitements sylvicoles (y compris la coupe) à l'échelle de la forêt. Cependant, pour faire en sorte que les modèles constituent un dosage optimal de simplicité, de généralité, de fidélité et de précision, il faut une certaine compétence. Deux applications récentes de la modélisation assistée par ordinateur pour la planifcation de l'aménagement forestier constituent deux courts exemples qui montrent comment ces modèles peuvent servir. On prévoit que ces modèles donneront une représentation améliorée des systèmes forestiers, et qu'ils seront plus facilement accessibles aux aménagistes et plus facilement utilisés par ces derniers. À mesure que leur usage s'intensifiera, le besoin d'aménagistes qualifiés en sylviculture ne diminuera pas, peu sans faut, mais les modèles leur donneront plutôt des occasions meilleures de se servir de leurs connaissances sylvicoles et de maîtriser, dans le temps, la mise en valeur des forêts.

Forest managers attempt to control development of a forest's structure over time, to produce goods and services. Full control is not achievable, but it is attempted by implementing silvicultural treatments, including harvesting, within a forest's stands. With limited funds for silviculture, and a desire to sustain or enhance forest productivity over time, forest managers must decide which stands should be treated, and how and when they should be treated, to make the best use of available funds. This task is complicated by the limited information available about the responses of stands to silvicultural treatments, and by the spatial and temporal scales of forest management (often involving thousands of stands over several decades).

Faced with this complexity, forest managers use simplified representations (models) of forest systems to help focus silvicultural effort. Such models range from rules of thumb and simple calculations to complex computer programs requiring large amounts of data, operator skill, and computer capacity. This paper discusses how models may be used to help plan the management of forests. Included are brief reviews of two recent projects in which models were used for this purpose. Finally, predictions are made about future prospects for modelling in support of forest management planning.

FOREST PLANNING MODELS

The component of management that is most amenable to support from models is planning, because planning involves developing and solving problem abstractions (models), and then translating the abstract solutions into specific solutions for implementation (Simon 1960). Figure 1 illustrates this role for models in planning and other forms of problem solving. For example, the "maximum allowable depletion" (MAD) calculations required for forest management plans in Ontario (Anon. 1986) are models of the behavior of forests under certain assumed conditions, in response to alternative choices of "rotation periods" (time between clearcut harvests), and "regeneration periods" (time between harvest and the achievement of free-to-grow status by subsequent regeneration). In the calculations, the maximum area within a forest from which timber may be depleted over the next 5-year period is estimated. Managers use the MAD calculations when they select allowable harvest levels. The MAD models are designed to assist managers in this task by temporarily simplifying some of the complexity of forest systems.

However, not all models are effective planning tools. Hall (1981) argued that, to be useful, models must be both understandable to decision makers and realistic in their reflection of system dynamics. Baskerville (1986) criticized the MAD models described above on these and other grounds. Clearly, there is a need for caution when selecting or developing forest planning models.

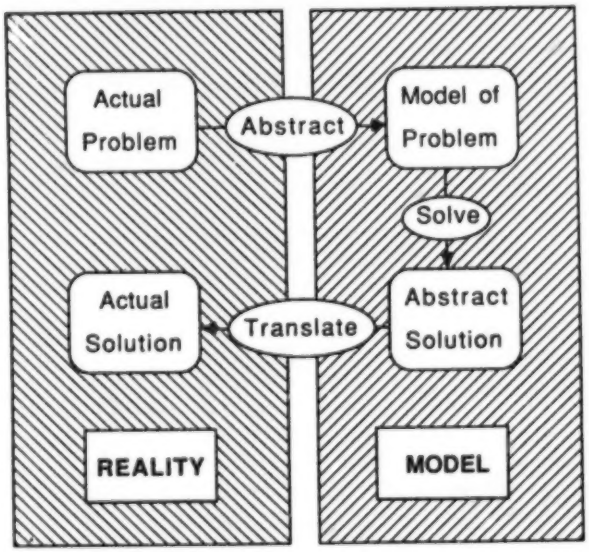

Figure 1. Planning models.

Model builders and model users recognize this need, and much has been written about how to develop, use, and assess quantitative models (e.g., see Levins 1966, Hall and Day 1977, Holling 1978, Duerr et al. 1979, Hann and Bare 1979, Hann and Brodie 1980, Hall 1981, Pierson 1981, Stage 1981, Dykstra 1984, Rose 1984). The advice given by these authors may be distilled into four fundamental model criteria: transparency, generality, accuracy, and precision. These conflicting criteria are discussed below.

Transparency is the degree to which the users (managers) understand the logical structure and flow of the model. Complex models may be rejected or mistrusted by forest managers because of their opaque, "black box" nature.

Generality is the degree to which a model used for one problem is appropriate for addressing related problems. A model that is

designed to address a particular problem but is not applicable elsewhere may be of less value than a model that addresses the problem less well, but is readily adaptable to addressing related problems. Models should also be flexible enough to incorporate changes in structure, as more is learned about the problem being addressed. The generality criterion acknowledges that the process of model construction is costly, and that it is therefore not feasible to develop a new model for each problem. A balance must be found between the value of insights obtained through use of models and the cost of developing models.

Accuracy is the degree to which the model reflects the processes of interest in the forest system. To be accurate, the model need not portray all system components, but the dynamics of those components included must be captured. Accuracy, therefore, determines the validity of model results. Strategies suggested by accurate models should be robust in that alternative, but also accurate, models of the same problem should suggest similar strategies.

Precision is the resolution of the model. Spatial and temporal resolution are critical model attributes, because of the spatial and temporal scale ranges of forestry. If managers are interested in tending options for individual trees within a high-value stand over the next 5 years, then the model used should not be designed to develop strategies for a remote township over several decades. Common sense will preclude such an extreme case. When resolution differences between the model and the problem are more subtle, however, such as when a stand-level model is used to design forest-level strategies, models may be misapplied. More precision is not necessarily better than less precision. Rather, model precision must be comparable to problem precision.

Transparency, generality, accuracy, and precision must be balanced when one is selecting or designing planning models. The key to achieving this balance is to ensure that the model adequately represents the forest system, so that abstract strategies designed with the model are seen by managers as analogs of practicable solutions to the actual problem. Thus, model adequacy is subjective; the best model for addressing a problem should be determined by, or at least in close association with, those managers who are accountable for any solution to the problem (Fig. 2). The case studies reviewed in the next section are offered as examples of how model adequacy can be achieved.

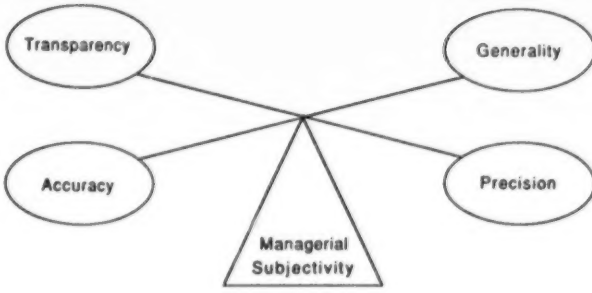

Figure 2. Model adequacey.

CASE STUDIES

These two modelling projects do not represent the full range of model complexity or of modelling approaches. In both cases, mathematical programming was used to design and evaluate alternative strategies for industrial clients. The first project was an economic wood supply analysis for a New Brunswick firm, and the second project was an operational schedule for the current portion of a management plan for an Ontario firm. In both projects, forest managers obtained useful planning insight through the use of models.

Economic Wood Supply Analysis

This project was completed during 1984 and 1985 for J.D. Irving Ltd. of Saint John, New Brunswick (Walker and Lougheed 1985, Walker 1986).

Irving staff were concerned about the long-term availability of softwood supplies from a forest area of about 200,000 ha. The study determined the costs of attaining various sustainable harvest levels over time. The approach was as follows:

- aggregate stand data into stand class data, ignoring geographic locations and age differences of fewer than 5 years;
- design a set of alternative crop plans for each stand class, including expected silvicultural costs and consequences;
- develop a model of the problem based on the Timber RAM modelling system (Navon 1971);
- use linear programming to find the least-cost strategy (assignment of crop plans to all stand classes) associated with attaining various sustainable harvest levels; and

- present the results to Irving staff.

As well as assessing wood supplies, the study showed Irving staff that silvicultural effort should be focussed on intensive tending of young softwood stands before additional plantations are established. Irving field and corporate staff were involved throughout the project, to ensure that the model was adequate for their purposes. The most compelling evidence for model adequacy is that the company is currently funding research into methods of extending the model results from management planning formats (stand classes and 5-year planning intervals) into operational planning formats (stands and 1-year planning intervals).

Still, the effects of compromises among the four modelling criteria are apparent. Irving managers have expressed concern that the model is difficult to understand and use (i.e., it is not transparent). Generality was not sacrificed, because the model was built within the limits of the Timber RAM modelling system. Only minor changes to this system were required to permit model construction. The generality of Timber RAM is shown by the range of its application (Beck 1984, Roberts 1984), and by the efforts being made to extend this range (e.g., Lougheed 1986). Model accuracy reflected the knowledge base of forest managers. Because Irving staff provided the forecasts of stand development after silvicultural treatment, these forecasts were credible to model users. Finally, model precision was sufficient for Irving staff to answer their question about economic wood supplies. The research mentioned above focusses on refining the precision of model-designed strategies, to improve the usefulness of the model as a planning tool.

Operational Planning

The second study was completed during the spring and summer of 1986, for the McChesney Lumber Division of E.B. Eddy Forest Products of Timmins, Ontario. This study has not yet been published.

Eddy staff were interested in selecting areas for harvesting operations over a 5-year period, such that harvesting and transportation costs would be minimized and wood delivery requirements for a set of mills would be met. The forest area (about 400,000 ha) had been subdivided into a set of major operating units (MOUs), each consisting of a set of stands with similar landform type, topography, location, age, and volume (Preiss 1986). Areas excluded from forest operations because of their location (e.g., lakeshore reserves) were designated separate MOUs. From the existing management plan, Eddy staff knew the MAD for the forest, and the MOUs eligible for harvest over the next 5 years. The area within the eligible MOUs substantially exceeded the MAD; consequently, Eddy staff had discretion in determining which areas to deplete. Furthermore, Eddy staff wished to consider alternative harvesting systems, and expected requirements for wood from nine combinations of species, mill location, and product, when selecting MOUs to deplete. If selected, MOUs would be fully depleted.

The approach used to address this problem was as follows:

- characterize each eligible MOU in terms of volume by species and cost of delivered wood to each mill;
- determine a set of alternative demand options for apportioning the MAD among the products and mills;
- formulate a model to reflect the alternative MOU, product, and mill selections;
- solve the model using integer programming; and
- present the results to Eddy staff.

Eddy staff used the study results in their selection of MOUs for harvesting, and in their choice of harvesting systems. As with the Irving study, Eddy staff were involved throughout the project to ensure that the model adequately reflected their problem. Most of this interaction occurred during the model formulation phase, in which several versions of the models were developed, discussed, and discarded before an acceptable version was found. Further modifications were necessary once preliminary results had been reviewed.

This model was therefore adequate, although it represented a compromise among the four model criteria that was different from the Irving model. Integer programming is a more complex technique than linear programming, yet the Eddy model was more transparent to Eddy staff than the Irving model was to Irving staff. In the Eddy case, the author's principal contact within the company had a working knowledge of mathematical programming techniques, and was therefore able to critique the model as it evolved. Consequently, transparency could be sacrificed in favor of accuracy and precision. Generality was not sought, although the model structure appears to have value for addressing similar problems for other firms.

FUTURE PROSPECTS

These two cases demonstrate that the appropriate model to use when addressing a forest planning problem is dependent upon the specifics of the problem itself. Transparency, generality, accuracy, and precision must be balanced in the development or selection of an adequate planning model. While this seems obvious, examples of inadequate models that are being used extensively, such as Ontario's MAD model, are still plentiful.

In future, better knowledge of the capabilities and limitations of quantitative models, such as is possessed by Eddy staff and is being acquired by Irving staff, will reduce the need for model transparency to some degree. Modelling efforts can then focus on improving accuracy and precision. Concurrently, scientists will continue to develop and exploit improved modelling techniques. The net result should be the use of more effective models, and perhaps there will be less need to be concerned with generality.

None of these developments will replace the need for both managers and modellers to improve their understanding of stand and forest dynamics, especially the mechanisms through which stands respond to silvicultural treatments. Models can assist here, by providing better frameworks for considering the forest management consequences of silviculture. If this is achieved, the evolution of modelling will be accompanied by an improvement in the ability of managers to control the development of forests.

ACKNOWLEDGMENTS

Forest management research is not possible without the active support and encouragement of forest managers. Staff of J.D. Irving, Ltd. and of McChesney Lumber are commended for their patience and for their willingness to consider scientific advice. Crandall Benson (Lakehead University) and John Garner (Great Lakes Forest Products) suggested useful revisions to earlier versions of this paper.

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THE ECONOMIC REVOLUTION IN FORESTRY

Dr. F. Miller, Chief Forest Economist
Ontario Ministry of Natural Resources
Toronto, Ontario

Abstract.--Numerous factors are speeding the introduction of economics into everyday forestry practice: pressure on governments to show return for dollars spent, increasing cooperation between industry and government in forest management, availability of user-friendly software for the microcomputer. Trends are away from theoretical work toward applied economics, away from specialization and toward the application of economic knowledge by the field forester. Future foresters will be forester-economists testing various options for site-specific, management unit, and regional decision making. Uncertainty provides the greatest challenge to economic model building, but can be partially overcome in the short run by solving for unknowns and experimenting with sensitivity analysis. The future will see increasing integration of management planning and economic analysis as linear programming and simulation techniques are used to forecast economic wood supplies and plan optimal silvicultural regimes.

Résumé.--Bon nombre de facteurs accélèrent l'implantation de l'économique dans la pratique forestière quotidienne: la pression exercée sur les gouvernements afin qu'ils rentabilisent leurs immobilisations, la collaboration accrue entre l'industrie et le gouvernement dans le domaine de l'aménagement forestier et la disponibilité de programmes de micro-ordinateurs faciles à utiliser. On aurait tendance à s'éloigner de la théorie et de la spécialisation pour se rapprocher de l'économique appliquée et du recours aux connaissances en économie par le forestier de terrain. À l'avenir, le forestier sera également un économiste mettant à l'épreuve diverses options de prise de décisions sur la station, l'unité d'aménagement et la région. Le principal problème de la modélisation économique est l'ircertitude; il peut être atténué, à court terme, par la résolution des inconnues et l'expérimentation de l'analyse de sensibilité. L'avenir nous réserve une intégration accrue de la planification de l'aménagement et de l'analyse économique, avec l'utilisation de la programmation linéaire et des techniques de simulation pour la prévision des approvisionnements économiques en bois et la planification des régimes sylvicoles optimaux.

Recently a colleague shared a "quotation of the day" with me. It went as follows: "Why is it that the same people who laugh at Gypsy fortune tellers take economists seriously?" The humor relies on the fact that most people see the economist as an aloof figure working in isolation on some abstract model designed to predict the movements of some more-or-less well known indicators in the more-or-less distant future, an individual who can be secure in the knowledge that the world will neither remember nor care whether the predictions in fact pan out. In the field of forestry the economist has been similarly viewed--in this case, as a remote individual working in isolation on some obscure models but with the variation that, from time to time, the economist calls to the foresters in the field to come up with some suitable numbers for the model to "crunch."

Today's developments are changing all of this. While we still have economists working on abstract models of the general economy and the academic arena still provides a home for the theoretical resource eonomist, the forest economist in government is moving toward the applied end of the spectrum. This means two things: applying economic principles and tools to practical problems for purposes of making decisions on the course of action to take, and developing the tools and making them available to foresters for their own use.

Two factors are contributing to these developments: the pressure for accountability and constraint in government, and the rise of the microcomputer. Increasing concern on the part of legislators to demonstrate that they are spending wisely and getting value for their program dollars is creating demand for financial analysis of program expenditures. This means having to demonstrate that the dollars spent will produce an acceptable return on investment.

Economists are model builders and the key part of their work is testing how their models perform under different assumptions. The development of the microcomputer has greatly simplified this work. The terms "model", "scenario", "simulation", "opportunity costs", "benefit-cost", and "sensitivity analysis" are no longer the trademark and patented property of the theorist linked with an umbilical cord to the mighty mainframe. Rather they are tools in the hands of anyone who can operate a micro. The microcomputer makes possible complicated and sophisticated analyses without expensive hardware and extensive programming knowledge. Its rapid calculations permit the ordinary user to explore quickly a number of different "scenarios", to become a "model builder."

So, economics has become applied economics, and the community of economists has expanded to include all interested parties who have the curiosity and tenacity to apply some economic tools to forestry problems. Yesterday the Ontario Ministry of Natural Resources (OMNR) had one or two economists. Today we have dozens, as field foresters, forest management supervisors and others pick up the economic tools of the trade and make them their own.

I would like to take this opportunity to review some of these developments in greater detail and point to where I think we are headed.

I referred to the distinction between theoretical economics and applied economics. This is much the same as the distinction between pure research and applied research. In the one instance the intent is to contribute to a body of knowledge with a payoff in the future. In the other the aim is practical problem solving through application of some tried and tested principles and relationships.

In the last several years we have made enormous strides at OMNR in applying economics to practical problem solving. In 1984 Peter Hynard, a unit forester in Minden District, did a study demonstrating how well known principles of forest economics could be used to examine practical questions facing field foresters charged with planning the forest of the future. In Case 1 he compared two options: 1) convert stands and manage for the desired species close to the mill, and 2) as he called it, "keep on trucking"--bringing wood in from distant sites that are regenerated because they happen to be where the cut is currently taking place. Net Present Value (NPV) analysis was used to show the amount that could be spent on conversion while obtaining the same level of return as on the cutover site. Anticipated transportation savings at time of future harvest were discounted back to show the amount of money the company could comfortably place in the conversion project.

In Case 2, Hynard expanded the analysis. Going beyond a simple comparison of two sites, he aimed at optimizing silvicultural investments for an entire management unit. The starting assumption was that the Forest Production Policy regeneration targets for the unit must be met. First, an inventory of cutover sites available for regeneration was drawn up. Sites were classified by soil characteristics and Forest Resource Inventory (FRI) site classes for the jack pine and poplar working groups. Three different silvicultural prescription series were worked up, Mean Annual Increments (MAI) were estimated, value added for the end product was established and the NPV of the treatment series was estimated for all poplar sites, for jack pine on deep, fine and medium sands, and for jack pine on sandy loam till soils.

In the next step in the process the package with the highest NPV rating was selected and applied against the land base available to it until that land base was exhausted. The next best option was then selected and similarly applied and so on until all production targets were met or all of the land base was used up (whichever came first). The end result was a schedule of hectares to be managed for each of the species in the best economic mix on sites on which there is the best return.

When this work had been completed the office of the Regional Forester in the Northeastern Region initiated a unique pilot study for North Bay District aimed at determining the optimal distribution of silvicultural dollars across the available sites. Working from detailed and ground-truthed soil survey data and on-site knowledge of forestry professionals, the researchers established the most compatible species and the choice of treatments for each site. Treatments were costed out on the basis of past silvicultural records. Monetary yields were determined by multiplying estimated gross merchantable volumes by the average economic value added per cubic metre of wood processed within the region. Sites were then ranked according to their NPV (expressed as an annual equivalent value).

At this point, mill demand was taken into account. Present mill demand was used to estimate how much of each species was needed and what the rotations should be. Transportation was also taken into account by assigning some sites a "distance penalty" if they were far from the mill. This enabled a modification of the original financial ranking of the sites. The end result was a model that allows us to determine the sites within the district that yield the best return for management investment and also meet market demand. This information permits us to concentrate dollars and staff so as to optimize forest management efficiency. Although no model can answer all the questions raised in a situation in which many management results are uncertain and socio-economic variables may change, it provides one tool for putting forest management on an economic basis.

It is of interest to note that other provinces are experimenting with similar approaches. With government support the Faculty of Forestry at Laval University is developing a model similar to that of the Northeastern Region to evaluate silvicultural alternatives on the university's Montmorency Forest. The territory for management is divided into "cells". For each of these an economic potential ("possibilité économique") is calculated that reflects both the value of the end product and an estimate of the "social benefit" of the activity less production costs and "externalities" (costs to society). A present value analysis is conducted with information on potential values, silvicultural costs, anticipated yields and rotations to produce a benefit/cost ranking of sites. Then various simulations or trial runs are conducted to meet different management objectives.

The Forest Economics and Policy Analysis Project in British Columbia recently conducted a study of the potential for rehabilitating the backlog of unsatisfactorily stocked forest lands that uses financial analysis to rank sites by compounding silvicultural costs forward to the expected rotation ages.

OMNR is now encouraging field foresters and others making day-to-day forestry decisions to apply the same economic concepts used in these exercises to determine whether a particular management regime makes sense from the perspective of return on investment.

Availability and reliability of data have always been problems for forest economists. In moving to an economic prime sites approach and away from a productive soils approach to forestry investment decision making we are entering a realm in which more of the variables are subject to fluctuation over time. We are also moving into an area in which many of the variables are subject to interpretation or judgment. How do we value the timber for the purposes of a NPV approach? Can we assume that today's values and even today's costs will remain in a constant relationship to each other in real terms? Will supply and demand in the future significantly alter the product mix and product values? Will management decisions themselves alter the supply and demand balance? A major data limitation is in the growth and yield area. We have as yet so little experience with the "new forest" and with different ways of managing the second growth that it is difficult to judge what our future yields and rotations will be. Since both the magnitude of the future crop and the time it takes to grow it are critical to economic analyses these problems seem to place almost insurmountable limitations on their use.

One of the ways we are getting around these limitations is a time-honored technique of the economist. I call it working forwards and backwards. Working forwards in the financial analysis formulas we take information we believe to be sound concerning results--expected yields, rotations and constant dollar values--use these to compute the present value, then subtract the present value of the costs we will have to incur to obtain those results. What we get is the NPV. This NPV can then be compared with that of a different management regime with different expected results and different costs. That's what I call working forwards.

If, however, we don't have a very good idea of what results we can produce with a

given management regime (or set of investments) we can still get some good mileage out of economic analysis. The process is comparable to fishing. We decide we want to catch a certain kind of fish of a certain size and ask what we would have to do to catch it--what kind of bait we would have to use, whether to troll or cast, how fast to troll, what line weight to use, etc. And we would determine this by trial and error over a number of fishing expeditions (with a number of cases of some well advertised beverage to compensate for the rigors of this scientific pursuit). Likewise with forest economics, operating in an area of many unknowns, we start with the assumption that we need to obtain a minimum NPV--say a break-even point of more than zero. Then we ask: what do we have to do to achieve this? What yields do we need to obtain this? What MAI do we need? What rotation length? If we achieve only yields of X and rotations of Y how much can we afford to spend? If we plan to spend X dollars what yields and rotations must we achieve to justify that expenditure in terms of a positive net discounted return? This is what I call working backwards.

I've used relatively simple examples but there are many more complicated cases that can be built up on this basis. Tree improvement provides some good examples. In this area the question has often been phrased: does tree improvement pay? Then the agonizing starts over how to be certain that the yields and rotations assumed for the new improved crop are accurate and defensible. Recently we have started viewing tree improvement through the backwards looking glass. The question now is: what level of improvement do we need to justify tree improvement? Our intensive management versus "keep on trucking" case could be profitably viewed in this same manner. Right now it might pay in many areas to keep on trucking. But how sensitive are the results of the analysis to changes in costs of transportation? A forester-economist working with a microcomputer program can quickly develop a number of options that will let us see how future changes in this key variable will affect the results of the model.

Risk is a very important consideration in any economic evaluation of the managed forests of the future. Computerized financial analysis techniques allow us to work backwards to determine what levels of risk are acceptable. We can then draw on our experience with fire, pests, disease and crop failure to determine if we can reasonably expect our risks to fall within those limits. As we get more precise information we can work forwards again.

A fancier name for what I have been describing is sensitivity analysis. The most practical way to deal with uncertainty is to carry out a sensitivity analysis for a given project. This entails testing the sensitivity of (or degree of change that occurs in) chosen measures of project performance under different assumptions.

First the main sources of uncertainty are identified. These are the parameters to be tested in the sensitivity analysis. For example, the forester might say, "I want to determine whether I should thin this jack pine stand or not but I don't have good data on the effects of thinning on yields." For each of the uncertain variables the investigator will estimate a reasonable range of values--in this example, a range of yields at expected rotation. He/she will then try to work out what effect the changes in values will have on the outcome of the project.

The office of the Regional Forester, Northern Region has been working on a variety of practical cases involving sensitivity analysis. These will be used in some of OMNR's financial analysis workshops in the near future.

There are still more sophisticated areas of economics in which microcomputers can be used to advantage. As recently as five years ago you needed a mainframe and/or a compulsive love of mathematics to consider linear programming solutions seriously. Now microcomputer software programs permit the development of linear programming models with thousands of variables and hundreds of constraints. Simulation is another technique that is increasingly accessible to the micro user. The OWOSFOP (Ontario Wood Supply and Forest Production Model) program currently available for the DEC Pro 350 is essentially a simulation tool that in the future may be adapted to incorporate economic variables.

Both linear and simulation approaches can assist us in analyzing long-term economic supply questions at all levels. We may not be at the point of putting consultants out of business but we are making it possible for more people to become acquainted with the assumptions underlying these kinds of techniques and to be able to interpret the results better, whether from a home-made model or from a consultant's more sophisticated version.

As noted above, an economist is basically a model builder. And the key requirement for the building of models is the courage to take a leap of faith into the unknown and make some assumptions. Many of you will have heard this story but I'll repeat it for those who haven't. An economist, an engineer and a physicist are shipwrecked on a small island. They

have nothing but a large can of beans, some driftwood and the hope that a ship will come within sight in the next few days. As their hunger increases they start to explore ways of opening the can of beans to sustain them until their rescue. The engineer says, "Why don't we use the driftwood to build a fire? We'll heat the can and it will eventually explode." The physicist agrees and adds, "Yes, and we will position the can *so* and I will plot the most likely trajectories so we can stand with our shirts ready to catch the beans as they fall." The economist looks at both with derision and says, "No, no, it's much simpler than that. *Assume* we have a can opener."

As an economist I have to be a believer in taking that leap of faith and in making assumptions. Many times we cannot move forward without doing so. But one of the great advantages of moving economics out of the head office and into the field is that we move the assumptions closer to reality and to practical experience. The field forester is in a far better position to gauge the likely results of any management regime on his or her home turf. Head office can help with data on economic variables, with passing on the tools, and often with fresh insights and approaches. But the "bottom line", I believe, is that the more the assumptions are grounded in experience, the better the models are.

Many will no doubt argue at this point that the increase in land under Forest Management Agreements (FMAs) will reduce the forester's need for economic decision making. This argument will run as follows. The companies are now responsible for management and for ensuring that management conforms to the rigors of financial tests. Many think that the FMAs mean that OMNR and its team are here only to act as biological consultants (gentlemen farmers), advising on different growth techniques and optimal biological rotations, and that we can leave the financial analysis to the companies.

But this is a mistake. With the growth in the FMA program there will be a shift in roles, but not along the lines that many foresee. I would argue that the FMA program increases the need for economic knowledge on the part of the unit forester, forest management supervisor, forest specialist and all of us charged with the responsibility for long-term viability of a public resource.

A friend of mine once considered going into a real estate deal with someone who owned a property with tremendous commercial potential north of Toronto. The second person had management expertise but insufficient capital to keep the investment till it bore a return. The first had enough capital to fill the breech but no management experience. A lawyer very wisely advised them against the deal. He said it had all the makings of a weak partnership. A partnership should not, he said, be a marriage of opposites. Each partner should have some strength in each of the critical areas to make the alliance work.

So it is with the FMAs. Yes, the companies are concerned with the economic "bottom line". But they, too, must take account of the long-term biological constraints and potential. Yes, OMNR has built a reputation for its expertise in forest management on the biological side, but it has an economic interest as well. It represents an important economic partner in this relationship--the people of Ontario as landowners. As representatives of the owners of the resource we have an economic objective and an economic "bottom line" to meet as well. That objective is to ensure the best use of the land in the sense of the best economic return to the land. On some occasions our economic interest and that of the companies may be in conflict. The long-term best use of the land may not always imply the lowest-cost management option in the short run. But over time these two interests should be more in harmony than in conflict. Nonetheless, it is the role and responsibility of the practising foresters in this province to be knowledgeable about the public's economic interests and to bring these to the discussions within the framework of the FMA partnership. This means having the knowledge to talk to companies in language they understand, in economic language, and having the tools to produce rapidly the information required to back up our convictions.

Where are we headed? The future will see increasing integration of economics and management planning as linear programming and simulation techniques are used to forecast economic supplies of wood and plan optimal silvicultural regimes. This integration will occur at all levels--site, unit, district, region, and province. Work at these levels will be complementary. It will be of little use to develop a large-scale model of the economic stock of timber for the province without a unit-by-unit appreciation of mill demand and the economics of future supply.

To sum up, today's foresters can and must be forester-economists. OMNR is in the process of creating an army of these forester economists. The economic specialists are the lieutenants in this army and the maneuvers are financial analysis workshops aimed at instilling the basic principles of economic and financial analysis and applying these principles by use of microcomputer programs. The result is nothing less than an economic revolution in Ontario forestry.

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WORKSHOPS

FOREST SITE QUALITY EVALUATION IN NORTH CENTRAL ONTARIO

W.H. Carmean, Professor
School of Forestry
Lakehead University
Thunder Bay, Ontario

A brief overview of the site quality research program at Lakehead University was given at the 1985 COJFRC Symposium (Carmean 1985). This 1986 COJFRC Workshop presentation more fully describes the major results of four completed studies.

A. Polymorphic Site Index Curves for Jack Pine (Lenthall 1986) and Black Spruce (Thrower 1986b)

Stem analyses from 141 site plots were used to compute site index curves for jack pine on the basis of breast height age. This study shows that: 1) site index curves based on breast height age were more precise than curves based on total age; 2) height growth patterns were similar for jack pine growing on four glacial landforms--shallow to bedrock, moraines, glaciofluvial and lacustrine soils; 3) polymorphic height growth patterns were related to level of site index, becoming more curvilinear as site index increased; and 4) height growth patterns were similar to Plonski's (1960) jack pine curves for ages less than 50 years, but after 50 years height growth for all sites was somewhat better than predicted by Plonski.

Site plots established by Lenthall (1986) in the study on jack pine site index curves frequently had a few dominant, free-growing black spruce trees. Stem analysis data from 44 plots were used to compute preliminary site index curves for black spruce (Grant 1984, Thrower 1986b).

B. Soil-Site Relations for Jack Pine (Schmidt 1986)

Soil-site relations were studied by Schmidt (1986), who used 99 of the jack pine site plots established by Lenthall (1986). Soil-site multiple regressions were computed for four major glacial landforms and were used to construct trend graphs illustrating relations between site index for jack pine and significant soil and topographic features; site index prediction tables were also computed for use by practising foresters in estimating jack pine site index on lands where trees are not suitable for directly estimating site index. An additional benefit is that features found to be significant can also be used for refining or defining landscape classification units described in the Ontario Forest Ecological Classification (FEC) Program (Sims et al. 1985) and the Prime Site Program (Nicks 1985). For example, soil depth and coarse fragment content were found to be consistently related to jack pine site index; therefore, these features should be emphasized in forest land classification systems with the goal of classifying forest productivity.

C. Site Index Curves and Growth Intercepts for Planted White Spruce and Red Pine (Thrower 1986a)

These results were based on internode measurements and stem analyses from 46 white spruce and 25 red pine plots. Thrower found that both species have slow and erratic height growth before reaching breast height; this early height growth is so erratic that only a very weak relationship was found between site index and years required to reach breast height. These results show that considerable error will be involved if this erratic early growth below breast height is included in site index curve computations. Accordingly, computed site index curves for planted white spruce and red pine were based on a breast height age of 15 and 20 years, respectively.

Growth intercepts for both white spruce and red pine were more precise when internode measurements were started somewhat higher than the commonly used breast height level. Growth

intercepts were started at the first internode above 2.0 m and 1.5 m for white spruce and red pine, respectively.

D. Site Quality Reduction for White Spruce Planted on a Log Landing (Thrower 1984)

Site quality in a 31-year-old white spruce plantation was drastically reduced when slash, surface organic layers, and surface soil were scalped from a lacustrine clay soil. The study area was an old landing where surface organic and mineral materials had been removed and deposited in a nearby windrow. This area had 31-year-old spruce planted on (1) a completely scalped area with mostly exposed clay subsoil, (2) a partially scalped area, (3) an area with little or no surface soil removal, and (4) an area to which organic and mineral material had been added.

Stem analyses show that, 31 years after planting, trees averaged 3.7, 6.4, 10.3, and 13.4 m for the completely scalped, partially scalped, undisturbed, and added soil areas, respectively. When these height growth curves are projected from 31 to 50 years (site index age) we estimate that site index will be 6.5, 11.7, 18.0, and 31.9 m, respectively, for these four areas.

This study showed a drastic reduction in site quality associated with removal of surface organic and mineral soil layers. The results therefore indicate that we should exercise caution in our site preparation practices. Severe methods such as straight blading may deposit large amounts of slash, organic layers, and surface soil in windrows and should be avoided. The most desirable methods of site preparation are those that leave surface soils in place rather than remove soil from the site.

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EFFECTS OF FOREST PRACTICE ON WOOD QUALITY

K.C. Yang, Associate Professor
School of Forestry
Lakehead University
Thunder Bay, Ontario

The wood properties of a tree can be altered to a certain extent within the limits of its genetic potential by manipulation of its growing environment. The most common methods of environmental control are spacing, thinning, fertilization, irrigation and pruning. The influence of silvicultural treatments on the six wood properties of softwoods, i.e., specific gravity, fiber length, growth ring, latewood percentage, juvenile wood and sapwood/heartwood, is summarized in Table 1.

Wood quality is defined as a measure of a wood property that affects the properties of finished wood products. Wood properties considered good for certain products may not be good for others. In general, the higher the density of wood chips, the higher the pulp yield. However, a high specific gravity of wood chips will adversely influence paper strength, especially bursting and tensile strength. A long fiber will be beneficial for paper strength, but a handicap for paper printing. The impacts of specific gravity and fiber morphology on pulping, paper making and paper properties are shown in Tables 2 and 3.

Table 1. Summary of influence of silvicultural treatments and rotation on softwood wood properties.

Wood properties	Age of tree	Silvicultural treatments					
		Spacing	Thinning	Fertilization	Irrigation	Pruning	Rotation
Specific gravity	young	±	±	±.n	±?	n	+
	old	-	±.n	-			
Fiber length	young	-	-	-	-	?	+
	old	-	-	-	-		
Growth ring	young	+	+	+	+?	?	-
	old	+	+	+			
Latewood (%)	young	-	-	±	±?	n	+
	old	-	n	-			
Juvenile wood	young	+	+	+	+	?	-
	old	n	n	n	n		
Sapwood/heartwood	young	+	?	?	?	?	-
	old	+					

+, positive relationship; -, negative relationship; n, no relationship; ?, unknown.

Table 2. Summary of impacts of specific gravity of wood on pulping, paper making and paper strength.

	HIGH sp. gr.	LOW sp. gr.
1. Chipping	1. harder to chip 2. increase chipper operation/ maintenance 3. more energy for chipping 4. more variable chip size - uneven cooking, e.g., oak, maple, hickory, ash, birch	1-4 easier, decrease or less
2. Pulping		
a) Cooking	1. greater weight of pulp per cook	1. reduce digester loading, energy saving
b) Cooking schedule	1. longer cooking time 2. more chemical consumption 3. mill production decrease 4. pulp quality decrease	1-4 shorter, less, increase
c) Treatment process	1. drain H_2O easily (free pulp)	1. drain H_2O with more difficulty 2. more easily collapsed fibers
3. Pulp yield	higher	lower
4. Paper weight	1. less fiber on a unit surface 2. less surface area per fiber because of high sp. gr. and thick cell wall	1. more fiber on a unit surface 2. twice as much surface area per fiber
5. Fiber coarseness	1. higher 2. increase fiber coarseness - increase stiffness - decrease collapse	lower decrease fiber coarseness - decrease stiffness - collapse more easily
6. Drainage	1. drain faster 2. reverse to lower sp. gr.	1. drain more slowly 2. collapse more readily to yield higher wet strength and higher sheet density
7. Paper strengths		
a. burst strength	decrease	increase
b. tensile strength	decrease	increase
c. tear resistance	increase	decrease
d. non-paper use (non-strength) requirement	bulkier	less bulky
(tissue, towel) (absorbent) (diaper)	more absorbent	less absorbant

Table 3. Summary of impact of fiber morphology on pulping, paper making and paper properties.

	1. FIBER LENGTH	
	Longer	Shorter
1. Pulping		
a. Washing	easier	more difficult - packed tight
b. Screen	more difficult	easier
2. Paper making	poor sheet formation	more even sheet
3. Paper strengths	cellulose increases as fiber length increases	
1. tear resistance	higher	lower
2. burst		
3. tensile	higher, but to a lesser degree	lower
4. folding endurance	than tear resistance	
4. Contact surface	greater area, greater stress can be tolerated	less area, less stress
5. Printing (cell type———	a handicap more vessel-lower pulp yield)	good for printing
	2. FIBER DIAMETER	
	Larger	Smaller
1. Sheet formation	collapse easily, more even	small and thin-walled fibers are good for sheet formation and strength
2. Bonding strength	higher (?)	(?)
3. Sheet density	denser (?)	(?)
	3. CELL WALL THICKNESS	
	Thick	Thin
1. Pulp yield	higher pulp yield-volume basis	lower
2. Sheet quality	1. coarser sheet, rougher 2. bulking sheet	finer and smoother sheet
3. Beating	3. harder to beat to a low freeness	
4. Strengths		
a. tear resistance	higher	lower
b. burst) c. tensile) d. folding)	decrease	increase
	4. L:T RATIO (length to cell wall thickness)	
	Increase	Decrease
1. Strengths		
a. burst	increase	decrease
b. tensile	increase	decrease
c. stiffness (MOE)[a]	increase	decrease

[a] MOE = modulus of elasticity

The length of rotation of a forest plantation has a direct impact on wood quality because of the larger proportion of juvenile wood encountered in a short-rotation stand (Fig. 1). Juvenile wood is generally characterized by lower specific gravity, shorter cell length, lower percentage of latewood, higher longitudinal shrinkage, higher microfibril angles, more reaction wood, lower cellulose content, lower strength, higher lignin content and a higher degree of knottiness than mature wood. The degree of rejection of juvenile wood lumber is very high because of its high degree of shrinkage and warping. Severely warped juvenile wood 2 x 4 studs cut from 30-year-old, plantation-grown black spruce and white spruce trees are shown in Figure 2. The potential loss, because of juvenile wood, could be as high as $80/MBF (MBF=1000 board feet) when juvenile wood content reaches 70% (Fig. 3).

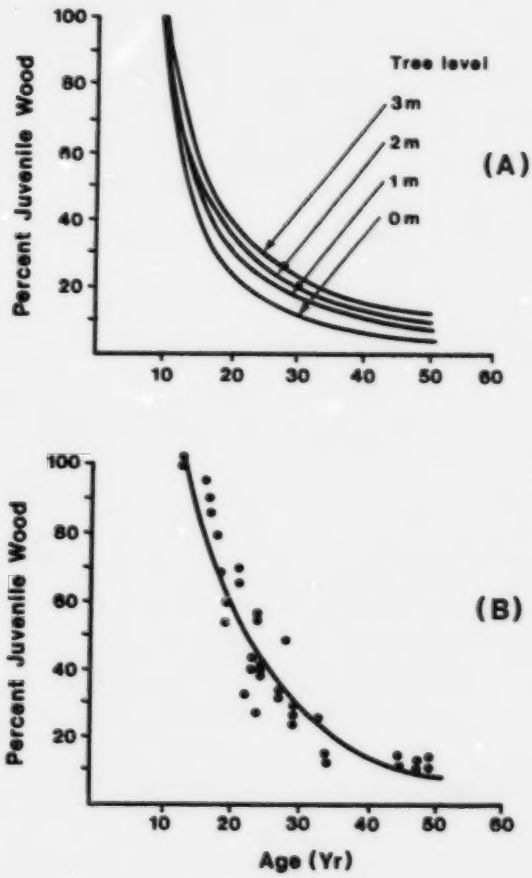

Figure 1. Juvenile wood volume (%) in (A) *Cryptomeria japonica* at various tree levels from the ground (redrawn from Mio et al. 1984) and (B) *Pinus taeda* of 22 trees each (Bendtsen 1978).

Figure 2. Severely warped juvenile wood 2 x 4 studs cut from 30-year-old plantation-grown black spruce (right) and white spruce (left) trees.

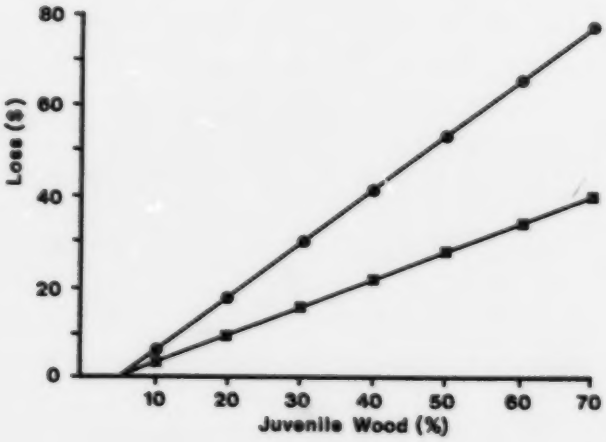

Figure 3. Potential loss due to juvenile wood for ● LAM stock prices and ■ STD and BTR prices in $/MBF (Redrawn from Smith and Briggs 1986)
(LAM=laminate, STD=standard, BTR=better)

The requirements of wood properties for various end uses are different from product to product. It may be useful to specify the end use of each plantation in a forest management plan. It seems that the control of juvenile wood formation for plus-tree selections is essential to the success of a forest plantation if the wood quality is of concern.

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THE USE OF MICROCOMPUTER SPREADSHEETS FOR ALLOWABLE CUT CALCULATIONS

C.A. Benson, Associate Professor
School of Forestry
Lakehead University
Thunder Bay, Ontario

Microcomputer spreadsheets were developed to allow students to examine the effects of different allowable cut methods on the structure of a forest. Technological developments in microcomputers and spreadsheets make such calculations easier and more versatile than before. It is difficult to ensure that students and practising foresters are kept up to date on new procedures because of the equipment that must be acquired and the new techniques that must be learned. It is hoped that this workshop session will acquaint them with some of the new technology and methods available.

Eleven different allowable cut worksheet were developed with the aid of VISICAI (Fylstra and Kling 1981) and were made avail able for student use (Benson 1985). Table illustrates one of the spreadsheets.

Spreadsheets were divided into fou classes:

1. 20-year period area allowable cut spread sheets that include normal, weighted, an FMA (FMA20) (Armson et al. 1980) methods

Table 1. Spreadsheet for calculating allowable cut by the second FMA method.

C.BENSON
SCHOOL OF FORESTRY
LAKEHEAD UNIVERSITY
1988

CALCULATION OF ALLOWABLE CUT BY FMAS METHOD (HECTARES) (VOLUME IN 1000 CU. M.)

MU
SPRUCE WORKING GROUP SITE CLASS ONE
ROTATION OF 120 YEARS. REGENERATION SUCCESS= 100 % REGENERATION PERIOD= 0 YEARS. FREE TO GROW AGE= 5 ASSUMED STOCKING= 80
YEARS OF GROWTH= 110
PLANNED STOCKING= 80

			NSR 5	NSR 3,4,6	NSR 2	1-20	21-40	41-60	61-80	81-100	101-120	120+	TOTAL BASE	TOTAL		
		AVERAGE			0	12.5	30	50	70	90	110	130				
	AREA OF REGEN	ACTUAL	1312	5378	18134	1046	1178	9742	8528	528	7284	19834	47940	70764	94.589358	
		MAI			0	0	0	5	10	1	9	22	51			
		VOLUME			0	0	7	484	706	58	960	2881	5076			
		NORMAL		0	2283	8549	9131	9131	9131	9131	4566	0	47940			57.5
		MORE			13851	0	0	611	0	0	2718	19834				
		LESS			0	5803	7953	0	603	8603	0	0				
		FIVE YEAR				0	0	0	0	0	0	3424	3424			1.5
0		MAI			0	0	0	0	0	0	0	4	4			
3424		VOLUME			0	0	0	0	0	0	0	502	502			
3424		AFTER	1312	5378	3424	18851	1232	7801	8832	2528	5595	19831	60850	70764	73.084838	
		MAI			0	0	0	7	10	3	7	20	46			
		VOLUME			0	0	7	362	732	279	738	2845	4762			
		TEN				0	0	0	0	0	0	3671	3670			1.2710407
5378		MAI			0	0	0	0	0	0	0	4	4			
3670		VOLUME			0	0	0	0	0	0	0	539	539			
9048		AFTER	1312	0	9048	19907	1286	5460	9135	4526	3909	18181	60403	70763	88.5(9142	
		MAI			0	0	0	5	11	6	5	18	45			
		VOLUME			0	0	8	280	757	499	515	2374	4412			
		FIFTEEN				0	0	0	0	0	0	3429	3429			1.192159
0		MAI			0	0	0	0	0	0	0	4	4			
3429		VOLUME			0	0	0	0	0	0	0	503	503			
3429		AFTER	1312	0	3429	28808	1341	3319	9439	4528	2217	14573	68022	70763	59.833108	
		MAI			0	0	0	3	11	8	3	10	42			
		VOLUME			0	0	8	158	782	719	282	2138	4088			
		TWENTY				0	0	0	0	0	0	3271	3271			1.0405758
0		MAI			0	0	0	0	0	0	0	4	4			
3271		VOLUME			0	0	0	0	0	0	0	480	480			
3271		AFTER	1312	0	3271	15901	17185	1178	9742	8528	528	13122	68179	70762	60.23794	
		MAI			0	0	3	1	12	10	1	15	42			
		VOLUME			0	0	102	56	807	940	70	1925	3900			
																1.0478183

Data entry points

2. 5-year period area allowable cut spreadsheets that include normal, weighted, the original FMA (FMA5), a revised FMA5 (SECOND FMA5), and the new FMA (FMA5 CROWN) (Anon. 1986) methods

3. sustained yield allowable cut spreadsheets consisting of maximum sustained volume (Clutter et al. 1983) and a rotation age sustained volume (SUSTAINED) worksheet

4. user-defined allowable cut spreadsheets that allow an individual to select the amount of the area to be cut.

The spreadsheets automatically calculate the areas by age class of the normal forest, the allowable cuts by four 5-year periods or seven to eight 20-year periods, and the volumes associated with those areas. For the user-defined spreadsheet, one enters the area to be cut and obtains the volumes associated with the cuts as well as the area structure of the forest after the cut.

More details on the spreadsheets may be found in Benson (1985, 1986).

The spreadsheets have been modified to take advantage of programs more recent than VISICALC, and of more powerful microcomputers. With all spreadsheets one can vary the data to observe results readily, but some possess features that make the process easier and faster. For example, the program FLASHCALC (Anon. 1984) for use on the Apple IIe allows cell protection, variable column widths, and automatic use of memory cards. More advances have been achieved with the Macintosh and the program EXCEL (Anon. 1985). Graphing features are an example (Fig. 1 and 2).

Even though the microcomputer spreadsheets allow students and a few Ontario Ministry of Natural Resources (OMNR) foresters to experiment with different allowable cut methods and to carry out allowable cut calculations more quickly and easily than previously, there are three main problems.

The first problem is that most students are not sufficiently educated in the use of microcomputers or spreadsheets to appreciate fully the logic involved in the allowable cut calculations. If the educational system can provide the required facilities, future students will probably be able to prepare their own complex spreadsheets, so that they can readily obtain the results and appreciate the calculating methods used.

The second problem concerns the ability of the educational system to provide microcomputers and programs in the future. In an industry as dynamic as the microcomputer industry, keeping up with the current technology is a costly process. By the time our school is able to upgrade our Macintosh computers to one megabyte, technology will probably be ahead of us by one or more steps.

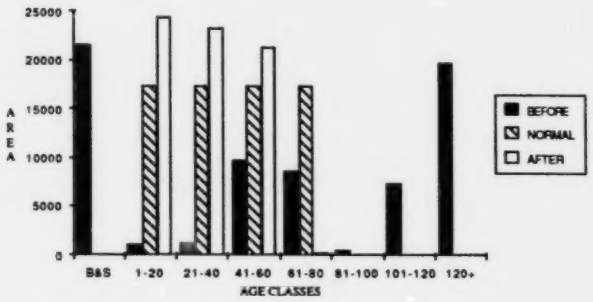

Figure 1. Distribution of area (ha) before and after eight 20-year maximum sustained volume cuts.

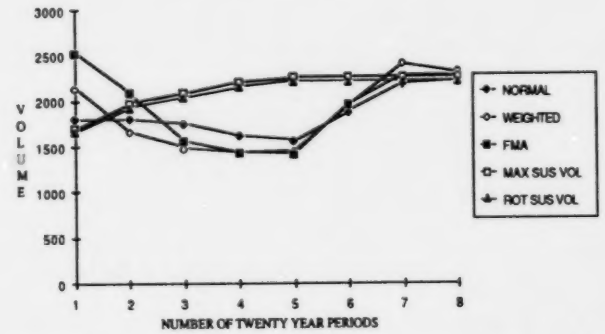

Figure 2. Allowable cut by volume (1000 m^3) for eight 20-year periods with five allowable cut methods.

The third problem is that the forest industry in Ontario and OMNR do not fully appreciate the capabilities of microcomputer spreadsheets. The majority of government foresters and all industry foresters to whom I have advised the use of microcomputers for allowable cut calculations have preferred to use a mainframe computer. This suggests that their organizations are not aware of the power of current microcomputers and spreadsheets and/or are not "lean and mean" enough to search for the most cost-efficient means of solving a problem. The microcomputer spreadsheets available now may not perform all the functions of the mainframe, but they do permit the use of OWOSFOP (Ontario Wood Supply and Forest Production Model) at the management unit level as suggested by Baskerville (1986). In addition, the spreadsheets are an excellent tool for compiling and keeping ledger data (Benson 1982).

It is hoped that this symposium workshop will introduce you to the "technological leading edge" of microcomputer spreadsheets.

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The assistance of Professors J. Tanz and D. Walker in preparing this paper is appreci ated.

MICROCOMPUTER SPREADSHEETS: AN INTRODUCTION

T.G. Eiber, Associate Professor
School of Forestry
Lakehead University
Thunder Bay, Ontario

Historical Perspective

Computers, as we know them today, were first developed during World War II and were initially used for breaking code and computing shell trajectories. During the 1950s, computers became large and powerful and began to find their way into large businesses and a few selected universities. As the 1970s began, most large corporations, government departments and universities had access to at least one computer, but until 1974, computers tended to be large, complex creations that required highly trained personnel and special environments. The user was rarely permitted to use directly the system that his needs had brought into existence.

In 1974, Intel Corporation introduced the first microprocessor, the 8008. It contained several thousand electronic circuits and, while we consider its power modest by today's standards, it was able to condense the function of a room-size computer of a few years before on a single silicon chip of several square centimetres. While this chip would be used in various applications, it was another chip, the 6502 from MOS Technologies, that would change computing forever when it was installed in the Apple II and Commodore PET personal computers (Norton 1984).

In 1977, Steve Wosniak and Steve Jobs integrated the 6502 and other components into a kit called the Apple I, of which about 500 were sold. About the same time, Radio Shack introduced another computer, TRS-80 Model I, based on the Z80 chip. Initially, both of these computers had moderate success in the market, but their use was generally limited to user-generated applications programmed in BASIC.

VISICALC: The First Spreadsheet

This situation changed in 1978 with the introduction of VISICALC. This program was the first piece of software commonly referred to as a spreadsheet. Since its introduction, it has sold over 400,000 copies, making it one of the most popular programs ever. As the first spreadsheet program, it set the tone and style for all the enhanced packages that have replaced it. VISICALC was created by a Harvard Business School student, Dan Bricklin, and a programmer friend, Robert Frankston, as a way to analyze detailed and intricate financial models (LeBlond and Cobb 1983).

General Spreadsheet Concepts

The concept of a spreadsheet program is quite easy to understand. Visualize a large sheet of paper that has been ruled off into rows and columns. In the case of the early programs, this paper was limited to 56 columns and 256 rows. Today, the standard spreadsheet, Lotus Development Corporation's 1-2-3, has 256 columns and 8192 rows (Anon. 1985).

In order to undertake any problem with a spreadsheet program, we first must be able to visualize the problem by writing down all the mathematical formulae, variables, and tables needed. In addition to our ruled paper (the screen), we need a pencil (keyboard), a calculator (the computer's CPU), and an eraser (a program command).

We normally begin by recording our numeric model on the paper, writing down the facts that we know (values) and adding some information so that the sheet is understandable (labels).

All information is entered into particular cells with locations identified by column (letter) and row (number). For example, cell Z45 is 26 columns to the right and 45 rows down. Cell A1 is the uppermost cell on the left side of the worksheet. At Cell AA120, we may scribe a table of variables such as a tax rate table, from which we will want to look up values. This area will contain at least two columns, the item to be looked up and the value being returned as the result of the operation. If this were a tax table, the income would be used to determine (LOOKUP) the tax rate.

Spreadsheets can become complex and quite intricate in their logic and calculations. Consequently, it is best to outline the problem before creating the spreadsheet model. My favorite strategy is to sit down with a piece of paper and map out the logic and flow of calculations in what is called a spreadsheet map (Anderson and Cobb 1984).

The spreadsheet becomes powerful because we can write formulae to undertake a specific calculation and then change the variables in that equation, as much as to say "What if ..." something were different. For example, the formula (B1*Z47+C1/100) might calculate the discount due a customer on the basis of volume of purchase. If B1 is the location of the purchase amount and Z47 the location of the standard discount, then changing B1 will cause this formula to return a different value when the model is run the next time. Further, if the result of this formula is used several times in other calculations, they, too, can be updated. Imagine our paper spreadsheet in this situation. We change one number and then use our eraser, pencil, and calculator to remove the old number, determine the new value, and write it on the paper. This procedure will have to be repeated everywhere on the sheet that is affected.

With microcomputer-based spreadsheets, this "recalculation" takes place automatically (unless you disable this feature). Therefore, when any number is changed, the entire system is updated on the basis of that new value regardless of the complexity of the analysis. Spreadsheets are therefore said to be interactive. Are you curious to know what effect a rise in the interest rate might have on the profitability of an operation? Change the interest rate and see!

Spreadsheets can also make logical decisions based on rules that you create. For example, the formula IF A1 AK31 will return a value of 1 if A1 AK31 (TRUE) or 0 if A1 AK31 (FALSE). If this were a harvesting model, you might inquire if the actual cut were greater than the allowable cut. The cell in which this formula is written will display either a 0 or a 1 which can be used in subsequent calculations to modify various aspects of the model.

Templates

Standard models may be saved on the disk with critical variable data missing (as blanks). This spreadsheet can then be called from the disk in the future and the data can be inserted to deal with a different situation. This standardized, saved model is called a "template". Using this technique, we can save many hours of rebuilding an analytical system for another task that was identical to a previous analysis. Some companies now offer standard templates as separate products to do defined repetitive tasks. Perhaps the best examples of these are tax preparation programs. These programs may even have the program print the answers on a copy of the tax form.

Graphics

Most members of the current generation of spreadsheet software now permit the user to display the spreadsheet information in a graphic form such as pie, line, or bar chart. This normally requires that the user organize his final answers into rows and columns. While the spreadsheets provide adequate graphics, the best graphics are normally provided by specialized business graphics software, such as Harvard Presentation Graphics by Software Publishing Corporation. This package permits the graphics package to read a spreadsheet file directly. Others may read the results of the spreadsheet that have been saved in a special file.

Import/Export

As spreadsheets become more sophisticated, the need to bring detailed information into a worksheet or to send the results of an analysis to another program becomes increasingly important. This is called IMPORT when the data are coming into the spreadsheet and EXPORT when data are being sent to another application (Anderson 1985). This capacity makes a spreadsheet an ideal vehicle for entering information to be used in other, more complex, operations (e.g., entering FRI information into a Geographic Information System). Data may also be exported to a statistical package for regression analysis or an ANOVA.

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NURSERY STOCK EVALUATION

R.J. Day, Professor
School of Forestry
Lakehead University
Thunder Bay, Ontario

This workshop focussed on evaluation of morphological and physiological quality of nursery stock for the improvement of survival and early growth of outplanted stock (Duryea and Landis 1984, Day et al. 1985, Duryea 1985, Navratil et al. 1986). The interaction of both bare-root and container nursery practices with the 'dormancy' cycle (Day 1985a) and with performance after outplanting was found to be *very important* when bare-root stock is lifted for overwinter storage in the fall, double cropping is practised by container nurseries, or stock is outplanted beyond the normal spring (or fall) season.

Three components of effective plantation establishment listed by Day and Harvey (1983) were reviewed:

1. the production of stock of desirable *morphological quality* (i.e., size or weight, form and color) and *physiological quality* (i.e., ability to regenerate and elongate new roots, absorb water from the soil, photosynthesize, develop buds during the first growing season after outplanting, and elongate satisfactory shoots the second growing season after outplanting);

2. the preparation of stock of high morphological and physiological quality at the nursery by growing and tending it in a manner that is in harmony with the 'physiological cycle' (and especially the dormancy cycle) of the stock, the monitoring and maintenance of high morphological and physiological quality of the stock during lifting, packing, and storage at either +2°C in the spring or -2°C over winter at the nursery, and during transport to and storage in the field);

3. the condition of the field planting site and microsites on which stock is to be planted for effective establishment of stock in terms of survival, root growth during the first season after outplanting and shoot growth thereafter.

The principal criteria used to quantify morphological quality of nursery stock were considered and methods used to measure the more important attributes of stock were discussed. Although the criteria for evaluating morphological quality of bare-root stock have been well defined (Day 1985b, 1986; Day et al. 1985), considerable work needs to be done on methods of evaluating the morphological quality of container stock.

The principal attributes of the morphological quality of bare-root stock were listed as follows: 1) height (cm), 2) root collar diameter (mm), 3) root area index (cm^2), 4) root volume (cm^3), 5) top and root dry weight (g or mg), and 6) top:root ratio. Height is measured with a ruler, root collar diameter with a caliper, root area index with an area meter such as a rhizometer or the Delta-T area meter, root volume by water displacement on a chemical balance, top and root dry weight and top:root ratio by determining the dry weight of the tops and roots after drying for 48 hours in a forced air oven at 70°C.

The principal criteria used to quantify physiological quality of nursery stock were considered and the methods used to measure them were described. At present the methods used to assess physiological quality of nursery stock are either empirical growth potential tests or simple measures of plant physiology such as plant moisture content or plant moisture stress. As with morphological quality, the methods for assessing physiological quality have been better defined for bare-root (Day et al. 1985) than for container stock.

The principal attributes of physiological quality currently considered important were listed in order of priority as follows: 1) root growth potential (the number of new roots), root number, or total elongation of new white roots, root elongation (in cm), which occurs 20 days after potting in standard soil mixture or placement in a root mist tank in a growth chamber programmed to provide an optimum environment, or after outplanting in the field, 2) plant moisture stress or negative water potential ($-\Psi$) measured in mPa or bars, 3) shoot growth potential measured in cm of terminal shoot elongation 20 and 60 days after potting in standard soil mixture in a growth chamber or after outplanting in the field, 4) mineral nutrient (N, P, K, Ca, Mg, etc.) or carbohydrate content at time of shipping from the nursery or outplanting.

Root growth potential is calculated by counting new white root tips or measuring newly elongated white roots with a ruler, a digitized pad interfaced with a computer, or an area meter such as the rhizometer or Delta-T. Plant moisture stress is measured by means of a pressure chamber. Shoot growth potential is calculated by measuring the length of the terminal shoot. Mineral nutrients and carbohydrate are measured according to well developed laboratory procedures.

The rapid development, during the last decade, of methods of evaluating morphological and physiological quality was discussed and related to the present situation in Ontario and in the Pacific Northwest of the United States where the principal work on stock quality monitoring is in progress.

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A PLACE FOR WILDLIFE IN INTENSIVELY MANAGED FORESTS?

H.G. Cumming and D. Barnes
School of Forestry
Lakehead University
Thunder Bay, Ontario

The workshop examined the proposition that intensively managed forests in Ontario are so small that they can safely be ignored for wildlife purposes; it went on to look at examples of possible management procedures.

The need for retaining wildlife habitat in intensively managed forests

The United States Soil Conservation Service has rated lands from Class 1 (primarily for row crops) through class VIII (suitable only for wildlife, recreation and watershed uses). In such a system, wildlife tend to be relegated to lands with the poorest soils, which, because they are poor, produce few wildlife. The Canada Land Inventory (CLI) has rated each possible land use without regard for current status, permitting comparison of areas rated for different uses. The CLI maps for forestry and ungulates near Timmins and Thunder Bay show strong tendencies for areas rated high for forestry to be rated high for wildlife as well. Good soils produce good crops of trees and wildlife, while poor soils produce few of either. If wildlife were excluded from intensively managed forests, they would be excluded from some areas with the highest capability for producing wildlife.

Discussion of prime site management in northern Ontario was hampered by lack of statistics on areas that might be affected. Some suggested that such areas would never be large and should be managed exclusively for timber. However, an example from Manitoba indicated that "the people" might decide they wanted wildlife on prime forest sites regardless of the effect on timber production. The question remained: can we afford to ignore the potential of these areas for producing wildlife? If prime site management is the wave of the future, we cannot wait until these sites become large and numerous before including wildlife in their management.

Some idea of the impact of excluding wildlife from intensively managed forests might be gained by looking at such forests in southern Ontario. Like prime sites in northern Ontario, individual areas seem small, but County Forests total 55,963 ha and forests on Conservation Authorities another 35,353 ha. If wildlife were excluded from these lands, 91,316 ha of valuable wildlife producing area would be lost. Furthermore, "even though Ontario's private, productive forest land is only 9% of total productive forest land by area, during the last two decades, Statistics Canada estimates it produced from a low of 16 per cent to a high of 39 per cent of Ontario's roundwood. Average production was 30 per cent." (Anon. 1981) One assumes the high production was due at least partly to better growth on these small, relatively rich areas; the same areas might also produce considerably more wildlife than their proportion of the total land base would suggest, and their locations close to population centers make them especially valuable for pursuits like bird watching.

What can be done for wildlife in intensively managed forests?

In Ontario, we are used to "featured species management" for wildlife; featured species include deer and moose. In areas with small, intensively managed forests, these forests should play a part in the wildlife habitat management strategy of a larger area. If intensive forest management becomes widespread, places will have to be reserved for wildlife. We may not be able to rely, as we have in the past, on our inability to implement intensive forest management as a way of ensuring good wildlife habitat.

The idea of managing for species richness is less well known in Ontario. The goal is to ensure that most wildlife species are main-

tained as residents of the managed forest in viable numbers (Thomas 1979). Only recently have wildlife biologists and foresters awakened to the value of non-game species, such as song birds, and the need for managing them; for example, in the United States, expenditures for bird seed, bird books, bird club memberships, and equipment like binoculars totalled about $500 million in 1975 (Robinson and Bolen 1984). This kind of use suggests that the demand for managing non-game species in Ontario may grow. Elsewhere it already has. Several acts in the United States have required foresters to produce wildlife from managed forest lands (Thomas 1979). In Australia, a head forester in one of the states was rumored to have been fired for being too commercially oriented.

The idea of deliberately leaving snags, as detailed by Thomas (1979) and Brown (1985), seemed preposterous until it was realized that only a specified number of snags per ha needed to be reserved, the number depending on safety considerations and on management decisions concerning how many of each wildlife species the manager wanted to retain.

Summary and Conclusions

Around the world, people are demanding a place for wildlife, even in intensively managed forests. Any government can change direction. We are likely to see more demands that wildlife be included in forest management in Ontario. We should begin working that way in intensively managed forests before someone forces us to do so. "Some will say it is too soon to undertake such a task (i.e., managing for wildlife in intensively managed forests), but there are really only two choices - too soon, or too late. With intensified forest management, impacts on wildlife will be magnified. The need is critical. The time is now." (Thomas 1979).

The question is: have we the will to do it?

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*Available from U.S. Government Printing Office, Washington, D.C., 20402.

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POSTERS AND DISPLAYS

GENETIC ENGINEERING OF FOREST TREES

W.M. Cheliak
Petawawa National Forestry Institute
Chalk River, Ontario

The soil bacterium, *Agrobacterium tumifaciens*, has the unique ability to transfer a specific piece of DNA to a plant cell, and cause this cell to express foreign genes. Transfer of the DNA is performed by the *Ti* (Tumor inducing) plasmid, and occurs when the bacteria attach themselves to wounded plant cells. This typically results in the formation of a tumor, commonly known as crown gall, because of the expression, by the plant, of foreign genes from the *Ti* plasmid. Foreign DNA, containing specifically selected genes, can be introduced into the *Ti* plasmid. These genes are transferred to the plant chromosome, along with *T* -DNA from the plasmid. The genetically engineered plant cells can be selected from the normal cells, further multiplied, and eventually grown into plants through tissue culture.

Genetic engineering provides geneticists with the ability to transfer genes across any species boundaries. At present, it can be used only for traits that are encoded by single genes. However, there is a growing number of single-gene traits that may be of interest to the forestry community.

REGENERATION PERFORMANCE SURVEY SYSTEM

D.G. Brand and P.S. Janas
Petawawa National Forestry Institute
Chalk River, Ontario

A prototype system to assess plantation performance on the basis of a biological free-to-grow standard is presented. The system uses a menu-driven, hand-held elecronic data collection unit (Husky Hunter) to obtain information on crop trees and competing species in the field. Data files are written from the Husky Hunter to an IBM PC in a format compatible with a FORTRAN summary and projection model. The model is employed to assess a plantation's free-to-grow status on the basis of algorithms of crop tree and competitor growth, and the user is enabled to project whether each tree is in danger of suppression. As output, tabular summary reports provide information on the plantation's free growing and potential stocking, the abundance and projected height of major competing vegetation, and the height growth trend of planted trees.

FACTORS INFLUENCING PLANTATION ESTABLISHMENT AND EARLY GROWTH

D.G. Brand
Petawawa National Forestry Institute
Chalk River, Ontario

Research into regeneration biology at the Petawawa National Forestry Institute is aimed at unravelling the site-specific determinants of productivity and at providing foresters with better tools to assist prescription development and growth diagnosis. The research project involves experimental plantations in three of Canada's major productive forest regions--the Boreal, the Sub-boreal Spruce, and the Great Lakes-St. Lawrence. Each plantation contains a series of plots treated to create different conditions of soil temperature, nutrition, and brush competition. Environmental conditions in these plots are continuously monitored with a variety of microclimatic sensors controlled by an electronic datalogger. Growth performance is monitored by means of a detailed annual bioassay of a sample of the trees in each plot. Correlation of the features of the trees with the availability of certain resources will indicate how trees acclimate to stress and where the greatest opportunity for productivity gains may be realized through the use of various silvicultural techniques.

FIRFOR

R.M. Newnham
Petawawa National Forestry Institute
Chalk River, Ontario

FIRFOR is a forest management model under development at the Petawawa National Forestry Institute. In its present form, it may be used to study the effects on long-term yield of fire and several other management options. Fire may be simulated through the use of a constant area burnt each year, or by drawing an area at random from a known Weibull distribution. The area burnt may be allocated uniformly to the age classes present or in proportion to the fire risk. The management options include harvesting the stands at prescribed ages that may vary with the site class, or harvesting to meet an Annual Allowable Cut (AAC). When an AAC is prescribed, the stands to be harvested each year are selected in order of either decreasing volume or increasing projected growth. (Stands with the greatest negative growth are selected first.) A proportion of the wood burnt in any year may be salvaged in the succeeding 1-4 years.

The ultimate goal of FIRFOR is to link up with a Geographic Information System and other databases, so that it can be used as a tool for making forest management decisions.

CONIFER MICROPROPAGATION

F.M. Tremblay
Petawawa National Forestry Institute
Chalk River, Ontario

Plant tissue culture is a powerful tool for forest tree improvement. Requirements for clonal material make urgent the development of reliable and efficient vegetative propagation techniques in forestry. Two different pathways of conifer micropropagation are being developed, one through organogenesis and the other through somatic embryogenesis. For organogenesis, epicotyls from germinated seeds are used. After two weeks on a bud-inducing medium, they are transferred to a cytokinin-free medium to allow bud development and shoot formation. The shoots are then elongated, rooted, and transferred to soil. For somatic embryogenesis, immature or mature embryos are dissected from seeds and cultured on a high-auxin medium to induce development of an embryogenic type of callus. Pro-embryo formation occurs in callus cells and is followed by their eventual development into embryos. These somatic embryos can then be used to produce artificial seeds, all of which are genetically identical to the original seed. The potential applications of each of these techniques are under evaluation.

APPLICATION OF LINEAR ARRAY IMAGER TECHNOLOGY TO FORESTRY

D.G. Leckie and A. Dombrowski
Petawawa National Forestry Institute
Chalk River, Ontario

S.M. Till, R.P. Gauthier, W.D. McColl and R.A. Neville
Data Acquisitions Division

and

F.J. Ahern
Applications Division
Canada Centre for Remote Sensing
Ottawa, Ontario

The advantages of linear array imagers are a good radiometric sensitivity, high spatial resolution, flexible waveband selection, and the ability to use narrow wavelength bands. The Multispectral Electro-optical Imaging Sensor (MEIS) system, operated by the Canada Centre for Remote Sensing, is a linear array imager which has eight spectral channels selected by optical filters and produces an image 1024 pixels wide. Resolution is 0.70 mr, which gives ground resolutions up to 0.35 m for most aircraft platforms. Inertial navigation system data can be used to record the aircraft attitude and position. With this information the imagery can be corrected to cartographic coordinates. By directing the field of view of one channel forward and another aft, one can also produce a stereo image.

Research with MEIS data has shown the high potential of linear array imager technology for several forestry applications. Enhancements of high resolution data (1 m) have indicated good species discrimination capabilities. Stereo data showing the relief of individual trees have been produced. Spruce budworm current defoliation has been deline-

ated with color composites of low-resolution (7-m) MEIS data and 0.4-m imagery shows cumulative defoliation on an individual tree basis. Clear-cut areas are easily discerned with low resolution imagery. Conifer regeneration as small as 0.7 m was consistently detectable on very high resolution (0.3-m) data.

With further development, linear array imager technology may provide an appropriate operational tool for forest inventory mapping, inventory update, insect and disease assessment, and sampling of various forest parameters. Key advantages are: a) better forest interpretations because of the ability to use optimized wavelength bands and enhance the display of data, and b) the efficiency of directly inputting the geometrically corrected data and interpretations in a forest inventory residing on a Geographic Information System.

FROM PLANTING TO PRINTOUT: ELECTRONIC DATA COLLECTION AND MAPPING WITHIN THE FAST GROWING FORESTS GROUP

D. Scale, L. Di Domenico, D. Smith,
and B. Hollingsworth
Fast Growing Forests Group
Ontario Ministry of Natural Resources
Brockville, Ontario

The Fast Growing Forests (FGF) Technology Development Group of the Ontario Ministry of Natural Resources is committed to the development and transfer of new technology for the intensive management of hybrid poplar, as well as several other fast growing hardwoods and some conifer species. The technology developed in this program is applied to growing crops on the better-quality forest sites close to the mill.

On an annual basis over 2 million measurements are collected from approximately 400 technology development trials. The data base is expanding at a rapid rate and currently consists of 140 million bytes of information. The rapid processing of this data is essential for the efficient transfer of technology (e.g., the identification of the most desirable clone to a specific site, or the identification of a suitable herbicide prescription) to target audiences. To increase the efficiency of the data handling process and shorten the turnaround time between collection and use of the analyzed data, direct data entry devices have been incorporated into the collection system. The FGF group's data collection program has been designed around the use of the Microflex '1'®.

A general program model has been written in the language Basic, which is adapted to the different trial types. Communication programs are written in Basic and compiled. The collected data are then loaded onto the main computer and analysis is conducted with the aid of SAS® (Statistical Analysis System).

To improve the data management system further the FGF group has implemented the use of AUTOCAD® for digitizing property soils maps. These maps are digitized to scale and the soil survey information is then superimposed on the original map with the use of overlays. As trials are designed, they can also be digitized and overlaid on specific soil types or areas of the property. Trials can have data attributed to them with special templates, and later these data can be extracted and set in a file that can be used by DBASE III®. In this way a large data base of several properties can be compiled, with specific data on each site.

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